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THE TEMPERATURE OF THE SURFACE OF THE SUN.

BY CAPTAIN JOHN ERICSSON.

From "Nature."

See Frontispiece.

It will be recollected that Messrs. M. E. Vicaire and Sainte-Claire Deville read some papers before the Academy of Sciences at Paris, last January, showing that the temperature of the solar surface does not exceed that produced by the combustion of organic substances. Their reasoning being based on the law of radiant heat, established by the investigations of Dulong and Petit, I have, in the meantime, instituted a series of experiments on a comparatively large scale, in order to test the correctness of the said law. Accordingly, the dynamic energy developed by the radiation of a mass of fused iron weighing 7,000 lbs. raised by "overheating" in the furnace to a temperature of 3,000 deg. F., has been carefully measured.

Sir Isaac Newton assumed that the quantity of heat lost or gained by a body in a given time is proportional to the difference between its temperature and that of the surrounding medium. Some eminent scientists, however, accepting Dulong's conclusions and formula, assert positively that the stated assumption is incorrect. In so doing they apparently overlook the conditions inseparable from the Newtonian doctrine, namely, that the conducting power of the radiating body should be perfect; that at every instant the temperature pervading the interior mass should be transmitted to the surface.* It needs no demonstration to prove that if the conducting power of a body be so perfect that the temperature of the centre is at all times the same as that of the surface—in other words, that the fall of temperature at the centre, occasioned by radiation, is as rapid as the fall of temperature at the surface, the rate of cooling of such a body will be very different from that observed by Dulong and Petit. The investigation instituted by those experimentalists has in reality established only the degree of conductivity of the radiators employed, under certain conditions, but by no means their true radiant energy at given temperatures. M. E. Vicaire and Sainte-Claire Deville, therefore, commit a serious mistake in assuming that the quantity of heat transmitted by the radiation of incandescent bodies at high temperatures has been determined. It may be observed that the relation between the time of cooling and

* The writer has just completed a set of experiments with a spherical radiator, 2.75 in. in diameter, composed of very thin hammered copper, charged with water kept in motion by a wheel applied within the sphere, revolving at a rate of 30 turns per minute, the centrifugal action of which brings the particles of the central portion of the fluid so rapidly in contact with the thin spherical shell, that the apparently absurd condition of perfect conductivity has been practically fulfilled. The result of carefully conducted experiments with this radiator, enclosed in an exhausted vessel kept at a constant temperature, has established that Newton's law relating to radiant heat, up to a differential temperature of 100 deg. Fahr. (beyond which the investigation has not extended), is rigorously correct. The subject will be fully discussed in a future article.

the *quantity* of heat transmitted by radiation which Dulong and Petit established, also misled Pouillet regarding the temperature of the solar surface, which he computed at 1,461 deg. C., or at most 1,761 deg. C. It will be well to bear in mind that Pouillet had himself ascertained with considerable accuracy the temperature produced by solar radiation on the surface of the earth; and also the retardation suffered during the passage of the rays through the terrestrial atmosphere. He was therefore able to demonstrate that the dynamic energy developed by solar heat amounts to nearly 300,000 thermal units per minute for each sq. ft. of the surface of the sun. Considering the imperfect means employed by Pouillet, his "pyrheliometer," the exactness of his determination of solar energy is remarkable. The truth is, however, that the near approach to exactness was somewhat fortuitous, the eminent physicist having underrated the energy of radiant heat on the surface of the earth, while proportionately over-estimating the retarding influence of the terrestrial atmosphere. The true dynamic energy developed by radiation at the surface of the sun, exclusive of the absorption of the solar atmosphere—no doubt exceedingly small—determined by the solar calorimeter mentioned in a previous article, is 312,500 thermal units per minute upon an area of 1 sq. ft. It will be proper to notice that this amount is not a mean result of a number of observations, but the greatest energy developed at any time during observations continued upwards of 3 years, namely, February 28, 1871. It will be proper to add that this result has been withheld from publication until it could be verified by a second observation indicating an equal energy. Fortunately the sky at noon, March 7, 1872, proved to be as clear as on the previous occasion referred to, the indicated energy differing only a few hundred units from that developed February 28, 1871.

Temperature being a true index of molecular and mechanical energy, conclusively established by the exact relation between the degree of heat and the expansive force of permanent gases under constant volume, it is surprising that Pouillet did not perceive that an intensity of 1,461 deg. C. or 1,761 deg. C., could not possibly develop on a single sq. ft. of surface the enormous energy represented by 300,000 thermal units per minute. M. Vicaire, adopting, like Pouillet, Dulong's formula, states in the paper presented to the French Academy that "an increase of 600 deg. is sufficient to increase the radiation a hundred fold;" and that Pouillet has verified Dulong's law to more than 1,000 deg. "Supposing," he observes, "that beyond this temperature the law ceases to be true, it cannot be absolutely remote from the truth for the temperatures of from 1,400 to 1,500 deg., which we deduce by adopting the law." Sainte-Claire Deville concludes his essay on solar temperature thus: "In accordance with my first estimate, I believe that this temperature will not be found far removed from 2,500 to 2,800 deg., the numbers which result from the experiments of M. Bunsen, and those published long ago by M. Debray and myself." The French *savans* then agree that the temperature of the surface of the sun does not exceed the intensity produced by the combustion of organic substances, their grounds for this assumption being, as we have seen, Dulong's formula relating to the velocity of cooling at high temperatures. But Dulong and Petit did not carry their investigations practically beyond the temperature of boiling mercury; hence their formula relating to high temperatures is mere theory, the soundness of which we have now been enabled to test most effectually by measuring the radiant power of a mass of fused metal raised to a temperature of 3,000 deg. F., 30 in. in depth, presenting an area of 900 sq. in.

Before describing the means which have been employed in measuring its radiant power, let us briefly consider the condition of the fused mass during the experiments. In the first place, the temperature has been sufficiently high to produce an intense white light, luminous rays of great brilliancy being emitted by the radiant surface during the trial; (2) the bulk of the fused mass being adequate, the intensity of radiation has been sustained without appreciable diminution during the time required for observation; (3) the temperature being higher than that which the French investigations assign to the surface of the sun, while the bulk, as stated, is sufficient to maintain the temperature of the fused mass, it may be reasonably asked, why an area of 1 sq.

ft. of our experimental radiator should not emit as much heat in a given time as an equal area on the solar surface, if its temperature be that assumed by Pouillet? It may be positively asserted, moreover, that an increase of the dimensions of our radiator to any extent, laterally or vertically, could not augment the intensity or the dynamic energy developed by a given area. Again, Dulong's formula, as applied by scientists, shows that the emissive power of a *metallic* radiator raised to a temperature of 3,000 deg., reaches the enormous solar emission computed by Pouillet.

Let us now briefly examine the calorimeter constructed for ascertaining the mechanical energy developed by the radiation of the fused mass under consideration. Fig. 1 represents a vertical section, and Fig. 2 a perspective view; *a* is a cylindrical boiler, having a flat bottom, composed of thin sheet-iron 0.012 in. thick, coated with lampblack. The cylindrical part of this boiler is surrounded by a concentric casing *b*, the intervening space being filled with a fire-proof non conducting substance. A horizontal wheel *c c*, provided with six radial paddles, is applied within the boiler, attached to a vertical axle, *d*. An open cylindrical trunk, *g*, is secured to the perforated disc which supports the paddles. The vertical axle passes through the top of the boiler, a conical pinion being secured to its upper termination. By means of a vertical cog-wheel, *h*, attached to the horizontal axle *k*, and geared into the conical pinion, rotary motion is communicated to the paddles. The centrifugal action of the latter will obviously cause a rapid and uniform circulation of the water contained in the boiler—indispensable to prevent the intense radiant heat from burning the bottom. The boiler and mechanism thus described are secured to a raft, *l l*, composed of firebricks floating on the top of the fluid metal. By this means it has been found practicable to keep the bottom of the boiler at a given distance, very near the surface of the fused mass, while by moving the raft from point to point, during the observation, irregular heating resulting from the reduction of temperature of the surface of the metal, under the bottom of the calorimeter, has been prevented. The radiant heat being too intense to admit of the axle *k* being turned directly by hand, an intervening shaft, 8 ft. long, provided with a crank handle at the outer end, has been employed for keeping up the rotation of the paddle-wheel during the trial. It is scarcely necessary to observe, that the intervening shaft should be coupled to the gear work by means of a "universal joint," to admit of the necessary movement of the raft. The experiment, repeated several times, has been conducted in accordance with the following explanation. The boiler being charged, the paddle-wheel should be turned at a moderate speed while observing the temperature of the water, the thermometer employed for this purpose being introduced through an opening, *m*, at the top of the boiler. The temperature being ascertained, the instrument should be quickly placed on the raft, and the time noted. As soon as vapor is observed to escape through the opening at *m*, the instrument must be instantly removed, the time again noted, and the temperature of the water within the boiler ascertained. It will be well to keep the paddle-wheel in motion until the last observation has been concluded.

The temperature of the fused metal having been as high during our experiments as that of the solar surface computed by Pouillet and his followers, while the thin substance composing the bottom of the calorimeter has been brought almost in contact with, and consequently received the entire energy transmitted by, the radiant surface, the reader will be anxious to learn what amount of dynamic energy has been communicated in a given time, on a given area. The desired information is contained in the following brief statement:—The necessary corrections being made for heat absorbed by the materials composing the paddle-wheel, etc., the instituted test shows that the temperature of a quantity of water weighing 10 lbs. avoirdupois has been elevated 121 deg. F. in 164 seconds (2.73 min.), the area exposed to the radiant heat being 63 sq. in. Hence a dynamic energy $\frac{10\times121}{2.73}\times\frac{144}{63}=1013$ thermal units per min., has been developed by the radiation from 1 sq. ft. of the surface of the fused metal maintained at 3,000 deg. F., against 312,500 units developed by the radiation of 1 sq. ft. of the solar surface, the tempe-

rature of which, agreeably to the calculations of the French *savans*, is less than that of our experimental radiator.

Having thus ascertained practically the amount of dynamic energy developed by the radiation of a metallic body raised to the high temperature of 3,000 deg., we have only to show in a similar manner the amount of energy developed by a metallic radiator of a low temperature, to be enabled to demonstrate the correctness or fallacy of Dulong's formula. Numerous experiments have been made for this purpose with apparatus of different forms, the results having proved substantially alike. The device most readily described consists of a spherical vessel charged with water, suspended within an exhausted spherical enclosure, kept at a constant temperature. Repeated trials show that when the differential temperature is 65 deg., the enclosure being maintained at 60 deg., while the sphere is 125 deg., the dynamic energy transmitted to the enclosure by a sphere the convex area of which is 1 sq. ft., amounts to 5.22 thermal units per minute. The accuracy of this determination is confirmed by the fact that during the summer solstice, at noon, when the sun's differential radiant intensity is 65 deg., the solar calorimeter indicates a dynamic energy of 5.12 units per minute on 1 sq. ft. of surface.

Our practical investigations, then, show that a differential temperature of 3,000 deg. develops by radiation a dynamic energy of 1,013 thermal units per minute upon an area of 1 sq. ft.; and that a differential temperature of 65 deg. develops 5.22 units per minute upon an equal area. The ratio of radiant energy at the first mentioned intensity will therefore amount to $\frac{1013}{3000} = 0.337$ unit for each degree of differential temperature; while for the low intensity it will be $\frac{5\ 22}{65} = 0.080$ unit for each degree of differential temperature. Consequently, the ratio of the radiating energy will be $\frac{0.337}{0.080} = 4.21$ times greater at 3,000 deg. than at 65 deg. Now, M. Vicaire, on the authority of Dulong, states that the ratio will be a hundred fold greater for an increase of only 600 deg. According to Newton's theory, based on dynamic laws, the proportion between the differential temperature and the radiant energy of bodies is constant; while Dulong and Petit, basing their conclusions upon an erroneous estimate of the time of cooling, assert that the ratio of energy increases several thousand times when the temperature is increased from 65 to 3,000 deg. Newton, then, as our experiments prove, is incomparably nearer the truth than the French experimenters; and possibly future research will prove that his law, when properly applied, will be found absolutely correct. It should be mentioned that the result of our experiments with the fused metal compared with the result of other experiments with solid metals at various temperatures, show that the emissive power of cast iron is relatively greater in a state of fusion than when solid, or merely incandescent. This observed increase of emissive power, now being thoroughly investigated, will no doubt account for the deviation from the Newtonian law indicated by the preceding comparison, which, let us recollect, is based upon the difference of radiant energy of fused metal at 3,000 deg., and solid metal at 65 deg. Considering this extreme range of temperature, and the totally different conditions of the radiators, the observed discrepancy is not too great to admit of satisfactory explanation.

The fallacy of Dulong's formula relating to high temperatures having been conclusively shown, it will not be necessary to examine the calculations of Messrs. M. E. Vicaire and Sainte-Claire Deville, presented to the Academy of Sciences at Paris. Besides, the question of solar temperature cannot be properly investigated without considering the leading points connected with the propagation of radiant heat through space—a subject of too wide a range to be discussed in this article. It should, however, be mentioned that the result of the measurement of solar intensity, March 7, 1872, before referred to, proves the correctness of our previous demonstrations, showing that the temperature of the surface of the sun is at least 4,036,000 F.

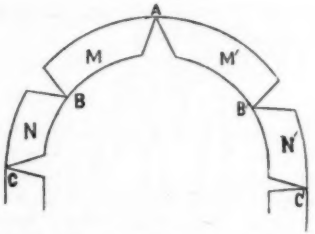
TELEGRAPHY IN FRENCH RIVERS.—Workmen have taken up two telegraphic cables laid down in the Seine between Rouen and Paris, shortly before the siege of Paris, to enable the capital, if invested, to communicate with the provinces.

THE STABILITY OF ARCHES.

Translated from "Sonnet, Dictionaire des Mathematiques Appliquées."

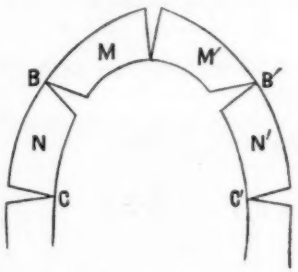
When an arch is about to give way, the effects are generally those represented in Fig. 1. At the crown, it opens on the side

FIG. 1.



of the intrados; on the flanks, at the extrados; at the springings, on the side of the intrados. It separates into 4 parts, M, M', N, N'. The first two turn about the points B and B', while the others fall outward, turning about C and C'. If the piers are not sufficiently stable they may turn with N and N'. In this case the rotation is about the outer edges of the piers. Again the piers may slide horizontally, instead of turning. More rarely an effect the inverse of the above is observed, as shown in Fig. 2. At the crown the open-

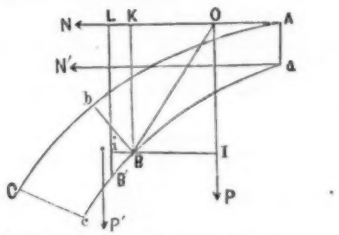
FIG. 2.



ing takes place at the extrados; on the sides, at the intrados; and on the side of the extrados at the springings. In this case the two upper portions rise about the edges B and B'; and the lower portions fall inward about C and C'. This kind of rupture happens in arches that are slender, high, and loaded heavily at the sides. To prevent this, pendant key-stones are employed, intended to increase the weight at the crown; and at the same time serving to receive ornament, as in Gothic churches.

I. That an arch may be in equilibrium none of the effects above described should ensue; and the theory of the thrust of arches aims to discover the conditions by which one may be assured of their stability. In case of an arch symmetrical with reference to a vertical plane through the intrados or extrados, one half of the arch is supposed to be removed, its place being taken by that of the reaction force. This reaction is necesarily horizontal, and perpendicular to the generatrices. Suppose Figs. 1 and 2 to represent a right section through the middle of the length. The mutual actions of the parts may be regarded as acting at N; these must be equal and opposed; and, as they are symmetrical with reference to the vertical at A, they must be horizontal and must act in the plane of the figure.

FIG. 3.



Let N (Fig. 3) = reaction of right half.
" h = its distance from B.
" H = " " " C.
" P = the resultant of exterior vertical forces acting on A B.
" p = distance of line of action of P from B.
" q = " " " " " C.
" P' = resultant of exterior forces acting vertically on B C.
" p' = distance of P' from C.
" R = absolute value of mutual reaction between A B and B C.
" R_x = horizontal projection of R.
" R_y = vertical " " "
" R' = reaction of pier upon B C.
" R'_x and R'_y = projections of R'.

For the equilibrium of the part AB we have

$$R_x = N \text{ and } R_y = P \qquad (1.)$$

and, taking moments with reference to the axis projected at B,

$$N h = P p \text{ or } N = \frac{P p}{h} \qquad (2.)$$

For the equilibrium of the semi-arch

$$R'_x = N \text{ and } R'_y = P + P' \qquad (3.)$$

and, taking moments with reference to the axis projected at C,

$$N H = P' q + P' p'$$
$$\therefore N = \frac{P q + P' p'}{H} \qquad (4.)$$

The first of the equations (3) shows that the horizontal reaction is transmitted to the abutment and is the force constituting the thrust. The second shows that the abutment also supports the weight of the arch and its load. The values (2) and (4) being equal,

$$\frac{P\ell}{h} = \frac{P q + P' p'}{H} \qquad (5.)$$

If this equation is not satisfied the static equilibrium of the arch is not assured. If it holds, then (2) or (4) give the amount of thrust. Finally equation (1) gives the components of the reaction R at B, and consequently the value of R itself.

II. The preceding calculation supposes the position of the point B to be known, *i. e.*, the joint of rupture B*b*. This position can be approximately determined by one of several methods. Suppose (in Fig. 3) A*a*, B*b*, repesents the whole of the first n voussoirs, reckoning from the crown A:—

P = their weight and load.
p = distance of the resultant vertical of this weight to B.
N = horizontal reaction at A.
h = distance of line of N from B.

That the arch may not open along B*b*, turning about B, we must have

$$N h > \text{or} = P p.$$
$$i.\ e.\ N > \text{or} = \frac{P p}{h}$$

Thus $\frac{P p}{h}$ is the inferior limit of the force N, in order that the rupture may not take place along B*b*. By determining this value for different values according to the number of voussoirs taken into account, the joint corresponding to the maximum value is found; and this is the joint of rupture.

The following method may be employed. Differentiate this expression, $\frac{P p}{h}$, making P, p and h vary, and make equal to zero.

$$h (P\,dp + p\,dP) - P p\,dh = 0.$$
$$h\,dp + h p \frac{dP}{P} - p\,dh = 0$$

But d P, which is proportional to the increase of volume of the arch, is an infinitesimal of the third order, while $d\,p$ and $d\,h$ are of the first. Hence

$$\frac{dp}{dh} = \frac{p}{h}$$

But if B′ is a point of the intrados infinitely near B, we have

$$p = B\,I,\ h = I\,O,\ dp = B\,i,\ dh = B'\,i.$$
$$\therefore \frac{B\,i}{B'\,i} = \frac{B\,I}{I\,O}$$

It follows that B O is in a right line with the element B B′; *i. e.*, it is a tangent to the intrados curve at B. Hence the joint of rupture may be determined by finding the point of the intrados where the tangent is drawn which meets the horizontal at its intersection with the line of P.

M. Petit has made out tables of values of the angle of rupture for a circular arch. We give an extract for an arch.

R = radius of extrados.
r = radius of intrados.
a = angle of rupture.

$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a
	° ′		° ′		° ′		° ′
2.00	57 17	1.60	63 49	1.40	63 48	1.20	59 41
1.90	59 37	1.55	64 3	1.35	63 19	1.15	57 1
1.80	61 24	1.50	64 9	1.30	62 14	1.10	53 15
1.70	62 53	1.45	64 5	1 25	61 15	1.05	46 32

$\frac{R}{r}$ 1, 5 gives the maximum angle of rupture 64° 9′.

For arches extradosed horizontally we have the following table :

$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a
	°		°		°		°
2.00	36	1.60	52	1.40	59	1.20	63
1.90	39	1.55	54	1.35	60	1.15	64
1.80	44	1.50	56	1.30	61	1.10	65
1.70	48	1.45	57	1.25	62	1.05	69

In this case the angle of rupture constantly increases with the value of $\frac{R}{r}$; that is, the joint of rupture moves further from the crown as the arch becomes more slender.

In arches with elliptical intrados, the point B, where the joint of rupture meets the ellipse, is sensibly at the same height above the springing, as in a circular arch with the same thickness at the crown and with radius of intrados equal to the semi-minor axis of the ellipse.

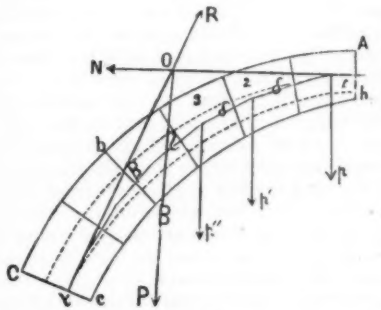
The same observation applies to *basket-handle* arches. In circular arches, properly speaking, there is no joint of rupture; since in practice the semi-angle of span, *i. e.* the angle between the radius drawn from the point of springing and the vertical, is generally smaller than the corresponding of rupture in a full centre-arch, having the same radii of intrados and extrados.

III. Instead of a sinking there may be a rising of the crown; then, instead of supposing the arch to open at *a*, *b*, *c*, Fig. 3, the points assumed are A, B, C. Rotation there takes place about *b* and *c*. By a process similar to the above we obtain the horizontal reaction N′ acting at *a*; this gives a second limit of thrust, which is larger than N since the distance of P from *b* is greater than that of *p*, while the distance of N′ from the same point is less than *h*. In a state of permanent equilibrium the reaction upon the joint A*a*, is applied at neither A, nor *a*, but at some unknown intermediate point; and its value lies between N and N′. The problem therefore is indeterminate, but this indetermination can be restricted within very narrow limits, if, instead of regarding the parts as incompressible, we take into account the compressions due to their mutual reactions. That is, the problem becomes definite, by treating it not only from a statical point of view, but also with regard to the stability of construction depending on the limited resistance of the materials employed. But, for this, it is necessary to admit the hypotheses relative to about the laws according to which pressure is distributed among the points of a plane surface of contact; and the consequence due to the fact, that, in order that there be no negative resistance at any point, it is necessary that the resultant of normal pressures, should not be applied at any point of the surface distant from an edge less than one-third the width of the prism measured at right angles to the edge.

Applying these considerations, in case of sinking of the crown, the point of application of the horizontal force N should be taken at a distance from A, equal to one-third the depth of the crown; in case of rising, the point is taken at the same distance measured from *a*. These two hypotheses will give two values of N, much more approximate than those obtained by the former methods; and between these two values, the actual value must lie. The same considerations apply at all the joints; so that by dividing each into three equal parts, and by joining with a continuous curve the points lying nearer the intrados, and by another curve those lying nearer the extrados, the limiting space of the curve of pressure is obtained.

IV. All indetermination is avoided by the use of the following graphic method, due to M. Méry.

FIG. 4.



Let A, C, *c*, *a*, (Fig. 4), be a semi-arch, of which the stability is to be determined. Take in the joint A *h*, a point *a* at one-third the depth from A; in like manner take γ in Cc. Let P be the resultant of exterior forces acting on the arch, including its own weight. Through *a* draw a horizontal line in the direction of the thrust N, cutting P at O. Join $o\,\gamma$, and this is the direction of the reaction R of the abutment. The semi-arch being maintained in equilibrium by three forces, it follows that the three lines of their direction pass through the same point. Each must be equal and opposite to the resultant of the two others. Resolving P into two components, along O *a*, and O γ the first gives the absolute horizontal value of N, the second, the absolute value of the reaction of the abutment. Now let *p*, *p′*, *p″*, etc., be the partial resultant of the exterior

forces acting on the several voussoirs taken in order from the crown. Voussoir 1 is in equilibrium by reason of N (which is known), p and the reaction r of 2 upon 1. Constructing the resultant of N and p, and reversing it, we have the reaction r; in its true direction it is r_1, the action of 1 on 2. Voussoir 2 is equilibrated by the force r_1, the force p, and the reaction, r^1 of 3 upon 2. The resultant r_1^1, and r^1 are found as before. Continuing this process through the successive voussoirs, the reaction of the voussoir next to the last (ρ), upon the last, is found. Compounding this with the exterior force q, we should have a resultant equal, and opposed to R. In this way the forces acting upon the successive voussoirs are completely determined. The broken line joining α, δ, ε, ζ, etc., γ, is called by Mr. Méry the curve of pressures.

That stability may be assured, it is necessary (1) that that the curve of pressure be included between the curves drawn trisecting the thickness of the joints, both on the side of the intrados and of the extrados. This is necessary, as above shown, that there may be no negative pressure at any of the joints. (2). It is necessary that, in the division of the component normal of the reactions N, r, r', r'', etc., by the surface of the corresponding joints, the result obtained should be at the most equal to the pressure which the material can resist. This limit in arches should be fixed at 50,000 kilogs. for cut stone, and 10,000 kilogs, for rubble. (3.) Again it is necessary that the angle of direction of these reactions with the joint surface should differ but little from a right angle. When one of these forces is oblique to the joint, it gives rise to a component along the joint surface which measures the tendency to sliding. The friction of stone upon stone is considerable, the co-efficient being 0.76; hence the reaction may make an angle of about 370 before sliding occurs. But it is prudent not to depend upon this resistance, as it may be much diminished, if at the time of decentring the mortar is not hardened. Hence the reactions should deviate little from the normal; and this principle especially applies to circular arches.

We observe that Mr. Méry's method makes no hypothesis with regard to the pirections of the forces p, p', p'', etc.; it is therefore applicable to all cases. The exact determination of these forces is the real difficulty met in the application of the preceding theory. If the arch supported a fluid, the pressure would be normal at every point of the extrados and would be easy to determine. If, as is generally the case, the arch bears a heavy mass of masonry, one does not know how its weight is distributed among the elements of the extrados. It is generally assumed that each voussoir sustains, in addition to its own weight, that of the material between vertical planes drawn through the generatrices which bound the particular voussoir. But it is obvious that this hypothesis is arbitrary, and that it must often be far from true. It has been proposed to take into account only the component normal to the extrados of the weight thus determined; a hypothesis just as arbitrary. Probably truth lies between these assumptions. In any event the weight of masonry should be estimated at 2,200 kilogs. to a cubic metre, and that of the surcharges at a mean of 1320 kilogs.

V. The methods described are at bottom only a system of verifications. Knowing the span and height of the arch, the curve of the intrados is determined. The thickness at the crown is determined by an empirical formula of Perronet. Let e be the required thickness and l the span of the intrados; then

$$e = 0^m,325 + 0{,}0347\, l.$$

The curve of the extrados is now assumed, and the investigation of the equilibrium and the stability is made. If the conditions are not satisfied the thickness is increased. If they are satisfied, trial is made to find whether they can be diminished; and thus by by repeated trials are found the dimensions most suitable, regard being had to solidity and economy of construction.

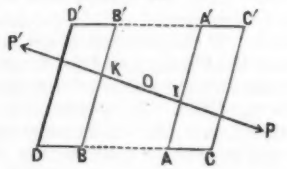
M. Ivon Villarceau, in a series of articles published in the "Revue de l'Architecture," and in a memoir entitled "Sur l' Etablissement des Arches de Pont," has attempted the problem in an inverse sense, and to determine at once the form of the intrados, the thickness at crown, and the form of the extrados; having given the span and height. He represented the conditions of the problem in equations by supposing a system of infinitely thin voussoirs, touching only at the generatrix;

and by means of laborious calculations demanding all the resources of analysis, he has constructed tables for determination of the various elements of an arch. It would be impossible for us to give his investigations in detail; but we observe that the intrados and extrados curves resulting from the theory of M. Ivon Villarceau differ little from the curves ordinarily employed; being slightly more spreading at the flanks.

VI. So far we have written only of right arches. In skew arches, at the time of decentring it is observed that the greatest contraction of material takes place in the direction of the right section; the influence is that the thrust is in a plane perpendicular to the axis of the arch. But it is not uniformly distributed through the length. This may be shown as follows:

Let ABB'A, CDD'C (Fig. 5.) represent the horizontal section at the springings of a skew arch; let O be the centre of the parallelogram.

Fig. 5.



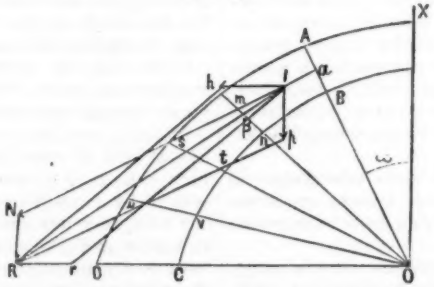
Draw through O, IK perpendicular to AA' and BB'. The total weight of the arch passes vertically through O. It can be decomposed into two others situated in the vertical plane whose trace is IK. The horizontal components are directed along IK; OP and OP' may represent these components, which constitute the thrust itself. The figure shows that the force P is nearer the acute angle A than to the obtuse angle A'; hence the thrust is unequally distributed along AA', and the angle A sustains the greatest strain. This result is independent of the coursing of the arch.

But another effect is produced in skew arches called the thrust *au vide*, and this depends on the coursing. This consists in the tendency of the voussoirs at the extremity to slide outward beyond the faces. This is apparent in the helicoidal coursing on account of the inclination of the helices which are the limits of beds of the voussoirs. It is not seen in the orthogonal coursing, especially when the cylinders which project the orthogonal trajectories on the head-plane are employed in setting the continuous joints of the head voussoirs. This is the chief advantage of this kind of arch, which is little employed because of the difficulties of execution. And it should be mentioned that in certain bridges near Paris constructed according to the orthogonal system the heads nave been strengthened by iron straps.

The most advantageous system of skew arches in respect to stability, is that composed of right arcs *en retraite;* the only inconvenience being a series of *redans* on the intrados side which have a disagreeable look.

VII. We how have to say a few words with regard to dome arches. Let A, B, C, D (Fig. 6), represent the section of an arch of this kind made by a vertical plane through O V. Let *a*B, *mn*, *st*, *nv*, DC, be the traces of the conic joints dividing the arch. Suppose the vault divided into *n* equal slices by planes through O V, making equal angles; and that the figure shows the section of one of these made by its vertical plane of symmetry.

Fig. 6.



Let P be the weight of the upper part

of the vault (dotted). A dome generally has to bear only its own weight: if otherwise, let the load be included in P. This may be resolved into n equal forces directed in the plane of symmetry of each of the n slices, normal to the upper conical joint. If AOX=a, the component acting on AB is $\frac{P}{n}$ sin.a; acting at a, which is taken so that no negative pressure may occur in B and so that A may not be crushed. This normal N compounds with p, the weight of the first voussoir, giving a resultant R. But this does not represent the pressure of the first voussoir upon the second. The vertical faces receive pressures from adjacent voussoirs which may be regarded as normal, giving, by reason of symmetry, a horizontal resultant in the plane of the figure. Besides, the condition may be assumed that the pressure of the first upon the second voussoir is normal to the conical joint between them. Decomposing R into h horizontal, and r perpendicular to $m\ n$; the latter will represent the pressure of the first on the second, and the former will be the resultant of lateral pressures. The force n compounded with the weight p' of the second voussoir gives a resultant R′ which can be decomposed as was done with R. All the forces acting on the several voussoirs are found by continuing this process. The last force r will give the normal pressure of the last voussoir upon the upper face of the circular supporting wall; the horizontal component is the thrust.

For equilibrium and stability it is necessary: (1) that the pressures r lie between the curves AD and BC; (2) that their points of application a, B, etc., shall not be so near either edge as to risk negative pressure of crushing at the edge; (3) that when the pressure is distributed upon the bearing surface the unit pressure shall fall within the limit of safety.

For prudence, the pressures should all be normal, as domes are ordinarily thin; but if the resistance of friction is considered, the forces N, r, r', etc., may have a certain inclination to the normal.

This method is obviously but an extension of the method of M. Méry. The conical joints may be divided into 3 equivalent parts by arcs or circles described from O as centre; and the condition may be imposed that the forces N, r, r', etc., shall all be comprised within the intermediate zone. If the conditions are not fulfilled, then the thickness of the dome must be increased or the curve of the extrados must be modified. In general, both in arches and domes, the thickness at springing should be greater than at the crown.

STANDARD vs. NARROW GAUGE.

By HERMAN HAUPT, Civil Engineer.

Written for Van Nostrand's Magazine.

The writer has received letters and personal requests for an opinion in regard to the advantages claimed for narrow-gauge railways. Time will not permit a separate answer to each, and he has, therefore, concluded to dispose of them collectively by an article for the "Engineering Magazine."

Narrow gauge has some advantages as compared with standard gauge, and some disadvantages. Its merits have been greatly exaggerated.

It is not fair to compare narrow-gauge railways equipped with light rolling stock, with the standard gauge on which necessarily heavy engines are used, and credit the saving entirely to narrow gauge.

A fair comparison, so far as the question of gauge is concerned, would be to put the light engines and cars of the narrow upon the standard gauge, and then note the cost of construction and operation.

Upon this, the only true standard of comparison, some of the claims of narrow gauge appear unreasonable and absurd.

It is unquestionably true that the excessive weight of cars and engines on ordinary standard gauge roads, and the excess of dead weight in proportion to paying load, increase greatly the cost of construction and of operation; but is such excessive weight necessary? In considering the relative advantages of gauges, it is unfair to assume different conditions; but the comparison should be made with similar equipments in both.

Take then the narrow-gauge cars and engines, extend the axles and cross-pieces

of car trucks 20½ in., give the axles increased size so as to to possess equal strength, let weights remain constant, wheels, car bodies, engines, all the same in both, and then compare the two systems.

The narrow gauge will have the advantage—

1. Of allowing about ¼ of a ton more load to a car, in consequence of reduced weight of axles and cross-pieces.

2. Reduced length of cross-ties, saving from $100 to $200 per mile.

3. Reduced width of road-bed of 20 in. This would save per mile, on an embankment averaging 10 ft., $100; on a side-hill cut of earth 10 ft. at upper slope, $50; Ballasting, $250. A little saving in width of bridges, which is almost inappreciable, as the trusses are the same in both.

4. Increased facility in turning curves, This is the greatest advantage as favoring economy of construction. The difference in length between the inner and outer rail with the standard 4 ft. 8½ in. gauge is very nearly 1 in. in 100 ft. for each degree of curvature, with a 10 deg. curve the difference in 100 ft. would be 10 in., and as the wheels are not permitted to turn on axles, there must be a slip to this extent. On a gauge of 36 in. a slip of 10 in. to 100 ft. would be due to a curve of 15½ deg. and it is possible that a curve of 15½ deg. on a 36 in. gauge would oppose no more resistance, than a curve of 10 deg. on a gauge of 56½ in.

The substitution of 15 deg. curves for 10 deg. curves may, in many cases, as on steep side-hill locations, result in great economy of construction, permitting the centre line to conform to the surface where curves of 50 per cent. greater radii would involve heavy cuts and fills, but this advantage is confined to localities where sharp curves and steep side-hills are presented. On level ground, or on curves considerably within the maximum limits, the saving secured by the use of narrow gauge would not be considerable.

As regards gradients it is believed that the advocates of the narrow gauge do not claim that an engine with a given weight on drivers, will haul a greater gross load on the same inclination, or a straight line in consequence of reduced width of gauge.

Assuming, therefore, the only true standard of comparison of cars and engines of equal weight on both gauges, the advantages of narrow gauge may be stated.

1. A slight saving in weight of axles and cross-beams, and an equal addition to paying load.

2. A saving in cross-ties, road-bed and ballast, as previously stated, of say $500 per mile, on an average.

3. A saving in cost of construction consequent upon the use of sharper curves.

These savings can only be determined in each case by a comparative estimate based on actual location, but they will not amount in the aggregate to 10 per cent. of the savings claimed by the advocates of the narrow gauge.

Economy, both in construction and operation, results from *low speed, light weight, and reduced proportion of dead to paying weight.*

The cars and engines on standard gauges are too heavy and speed too great. When engines of 10 tons were used the durability of rails was almost indefinite, and breakages of very rare occurrence.

Come back to light weight of rails and rolling stock, and moderate speeds on standard gauge roads, and the advantages claimed for narrow gauges will be much reduced.

Many of the claims of the advocates of narrow gauge are preposterous, and will not bear investigation. For example, in a pamphlet before the writer it is claimed that the 36 in. gauge willl effect a saving of 25 per cent. in right of way.

It is usual to take four rods in width, and the same quantity would no doubt be taken, even if the gauge should be reduced 20 in.; but conceding that a proportionate reduction should be made, the percentage saved would be less than 3 per cent., even assuming that the damages paid are in proportion to area of land condemned, which is far from correct.

It is also claimed that 25 per cent. is saved in ditches, and in formation of road-bed, by reduced width of 20 in. This is also extravagant, for the ditches drain the slopes and often a large area above the slopes, and are not affected by width of road-bed.

It is conceded that stability is impaired by narrow gauge when speed is high, but sufficient weight is not attached to this objection. In 1847, a part of the Susquehanna bridge on the Penna. R. R., while in progress of construction, was blown down by a high wind, and calculation proved that winds are occasionally high enough to

blow over a train of cars on a level track, even of standard gauge. The tendency to blow over would be increased on a narrow gauge, particularly if a rocking motion should be communicated to cars by inequalities in the surface of the track.

These criticisms are not designed to discredit narrow-gauge roads, which are destined to play an important part in the economy of transportation; they are introducing a much needed reform, but let not the narrow gauge be credited with economies resulting from light weight and moderate speed, which are not necessarily confined to it but may be introduced with almost equal advantage on roads of standard gauge.

Narrow-gauge roads as feeders for trunk lines of standard gauge involve transhipment at their termini, and separate equipment for their operation, which cannot be transferred from one road to another with facility as needed. This is a very serious drawback to their use in coal transportation. The transhipment of coal, especially of the softer kinds, is attended with great breakage and waste, and a system which would prevent main line cars from loading at branch road collieries, will not soon be looked upon with favor where coal operations are extensively carried on.

The writer has used a wooden railroad in lumbering and other operations, which for such purposes possesses great advantages. It consists of hewed timbers 6 in. square, laid in trenches and filled in so that the surface of the timbers is flush with the surface of the road-bed. No cross-ties or rails are used, the timbers themselves form the rail. The wheels are made of wood, pieces of hard wood cut in form of circular sectors nailed to break joints, one over another, so as to give a tread of 6 in. The flange is a ring of cast iron bolted on the wheel, boxes of cast iron inserted and wedged in middle of wheel. Such tracks can be laid on common earth roads, without obstructing their use for carts or wagons; as nothing projects above the surface they are particularly valuable in railroad cuts where carts and cars can be use at the same time, without interfering with each other.

CAPACITY OF NARROW-GAUGE ROADS.

The capacity of a railroad is often limited by the facilities for handling freight at its terminus, but where such facilities are ample, the capacity will be measured by the load of the trains and the number arriving in a given time.

The question of speed affects the capacity of a given equipment, but not the capacity of the road itself. At slow speed more cars and engines must be used to carry a given tonnage; but the destructive effects of speed both on permanent way and rolling stock increase in a much higher ratio than the velocity.

The load of an engine of given weight on drivers is determined by the maximum resistance offered by grade and curvature on the division over which it travels, or by grade alone when full compensation has been made for curvature.

The interval between trains must be sufficient to switch off a train or give notice of accidents or obstruction; to guard against rear collisions, 15 min. will be assumed as a minimum.

On a freight road worked nearly to the limit of its capacity, a double track and uniform speed will be essential, and separate tracks must be provided for passenger trains requiring higher speed.

The standard freight engine on Pennsylvania Railroad weighs 75,500 lbs., weight on 6 drivers 53,000 lbs., weight of tender with coal and water 50,000 lbs. The tractive power of such an engine on a level is 1,210 tons gross load.

Assuming for narrow-gauge roads an engine with 6 drivers and no truck, weight on drivers 27,000 lbs., tender 27,000 lbs., cars as is claimed, of 2 tons carrying 6 tons. The load on different grades would be, in tons of 2,000 lbs.

	Gross load. Tons.	No. of Cars.	Freight. Tons.
Level	605	72	432
10 p. grade	425	49	294
20 "	332	38	228
30 "	275	31	186
40 "	228	25	150
50 "	197	21	126
60 "	174	18	108
70 "	155	16	96
80 "	140	14	84
90 "	128	12	72
100 "	118	11	66
110 "	109	10	60
120 "	100	9	54
130 "	95	8	48

Assume now, that the ruling gradient which determines the load of the trains on a narrow-gauge road, is 50 ft., and that higher indications are overcome by assistant engines. Two engines would carry the train over a grade of 105 ft. The capacity

of the road can now be determined. Load of trains, 126 tons.

Intervals 15 min., 24 hours per day, 300 days per year; trains per year, 28,800; tons per year, 3,628,800. On a ruling gradient of 80 ft. and maximum of 152 ft., the capacity of the road would be 2,619,-200 tons.

These are very satisfactory results, but some of the advocates of narrow gauge claim for such roads a carrying capacity of 10,000,000 of tons of paying freight and assume data to figure this amount, but they ignore the fact, that grades influence the size of trains, and the carrying capacity of the road.

COMPRESSED AIR ENGINES.

From "Engineering."

It may be remembered that in a former article, we advocated a low piston speed for compressed air engines on the score that by the adoption of such moderate speeds a greater facility is afforded for imparting heat to the air during its expansion, and we further recommended, as a convenient mode of imparting this heat, the immersion of the cylinders and of the main air reservoir in a hot-water jacket. At the risk of some slight repetition, it may be desirable, perhaps, that we should briefly state here the way in which the absorption of heat takes place in a compressed air engine. We will suppose the engine to be of that class in which the air stored up at a high pressure in a main reservoir is allowed to flow thence through a reducing valve into an intermediate chamber, whence it is supplied to the cylinders. If the air is worked expansively in the cylinders, as it ought to be, the absorption of heat during each stroke may be divided into two distinct stages. In the first place, while the admission port is open the piston will be urged forward by the direct flow of air from the intermediate chamber, or, in other words, by the expansion of the air in the main reservoir; while after the cut-off takes place the work will be done by the further expansion of the portion of the air shut into the cylinder, and the expansion of the air in the main reservoir (supposing the latter to be supplying one cylinder only) will cease. The expansion, whether in the main reservoir or in the cylinder, will, unless heat be derived from external sources, be accompanied by a reduction of temperature of the air, and it is this reduction of temperature beyond a certain point which it is desirable to avoid, in order to do away with the trouble attendant upon the freezing of the moisture which the air contains. As we pointed out in our former article, one mode of preventing the attainment by the air of a very low final temperature would be to impart to it a high temperature in the main reservoir, so that, even after expansion, the temperature might not be so low as to allow of the freezing of the vapor; but, as we then stated, this mode of procedure is open to important practical objections, and it appears to be altogether the best plan to supply the air with heat at the time when the expansion renders that heat necessary. In other words, we believe it to be the best plan to apply heat to both the main reservoir and the cylinders, and we do not at present see a more convenient mode of applying that heat than by a simple hot-water jacket. The intermediate chamber may or may not be included in the jacket, as may be most convenient, there being no absolute necessity that heat should be applied to it, as in passing through it the air does no work.

These preliminary matters being stated, we may proceed to the special object of this article, namely, to show the quantity of compressed air which is required to perform a certain amount of work, and the quantity of heat which it is necessary to supply to avoid the freezing of the moisture. The best way of dealing with these points will probably be by considering a particular example, and we shall therefore suppose a case in which a load of 6 tons, including the weight of the machinery, has to be drawn at a speed of 8 miles per hour over a line 4 miles in length,

of which 3 miles are level, while the 4th mile rises with a continuous gradient of 1 in 56. Further we will suppose the line to be a tramway laid through the streets, and that in consequence of the dirt, etc., on the rails, the resistances at the speed above mentioned reach 20 lbs. per ton. In this instance the tractive force required on the level portion of the line will be $6 \times 20 = 120$ lbs.; while on the gradient it will be $120 + \frac{2240 \times 6}{56} = 360$ lbs., or 3 times the tractive force required on the level. Let us further suppose the driving wheels to be 3 ft. 6 in. diameter, and the two cylinders to be $4\frac{1}{2}$ in. diameter with 12 in. stroke, the connecting rods being coupled direct to driving axle. The circumference of a 3 ft. 6 in. wheel is 11 ft. almost exactly, and with the above-mentioned proportions the piston speed when the vehicle was moving at 8 miles per hour would be $\frac{5280 \times 8 \times 2}{11 \times 60} = 128$ ft. per min., a very moderate speed, suitable for the ready absorption of heat by the air during its expansion in the cylinder.

When ascending the gradient of 1 in 56, the tractive force required being 360 lbs., and the wheels and cylinders being of the dimensions already given, the mean effective pressure on each piston would have to be:

$$\frac{360 \times (3.5 \times 3.1416)}{1 \times 4} = \frac{360 \times 11}{4} = 990 \text{ lbs.}$$

while on the level portion of the line 1-3d this pressure, or 330 lbs. only, would be necessary. In such an engine as that of which we are speaking, the mean losses due to back pressure, pre-exhaust, compression, and wire-drawing at the point of cut-off, etc., may be estimated fairly as equal to a mean back pressure of about 9 lbs. per sq. in. above the pressure of the atmosphere, or, say, a total mean back pressure 24.7 lbs. per sq. in. measured above a vacuum. If now we decide upon the ratio of expansion, the quantity of air used and the initial pressure necessary can be readily calculated.

If air was capable of absorbing heat rapidly from surrounding objects it might be possible to carry out the expansion in the cylinder to a very considerable extent without much inconvenience, although even in such a case it might rather be desirable, on account of the difficulty of keeping pistons and stuffing-boxes thoroughly air-tight, to avoid the use of very high initial pressures. As it is, however, there is another reason for keeping the amount of expansion within moderate limits, and this is the comparatively slow rate at which the expanding air is capable of absorbing heat from the surfaces with which it is in contact. Taking this fact into consideration we believe that a fourfold expansion in the cylinder will in most cases be found as great as is desirable; and assuming this to be the degree of expansion decided upon for the engine forming our example, when working on a level, we may proceed to calculate the initial pressure necessary. The diameter of the pistons being $4\frac{1}{2}$ in., the area will be 15.9 in., and the mean effective pressure required on each piston being 330 lbs., the mean effective pressure per sq. in. will be $\frac{330}{15.9} = 20.75$ lbs., which, added to 24.7 lbs., the mean total back pressure, gives 45.45 lbs. as the average *total* pressure required on the piston during the stroke. With a fourfold expansion the mean total pressure is equal, as is well known, to:

$$\frac{\text{initial pressure} \times (1 + \text{hyp. log. } 4)}{4},$$

or if, as in the present instance, the mean total pressure be given, the initial pressure $= \frac{\text{mean total pressure} \times 4}{1 + \text{hyp. log. } 4} = \frac{45.45 \times 4}{1 + 1.386} = \frac{81.8}{2.386} = 76.1$, or, say, 76 lbs. per sq. in. total, or 61.3 lbs. above the atmosphere. At the same time the final pressure after expansion will be $\frac{45.45}{2.386} = 19$ lbs. total.

When working up the gradient the main effective pressure required in the cylinders would be $\frac{990}{15.9} = 62.26$ lbs. per sq. in., which added to the back pressure as before gives $62.26 + 24.7 = 86.96$ lbs. per sq. in. as the average total pressure on the piston. With such a high mean pressure it would be far from desirable to resort to any great degree of expansion, and when working on the gradient it would probably be found preferable to make the cut-off no earlier than is desirable for the purpose of insuring a free exhaust. Thus a cut-off at three-fourths of the stroke might probably be adopted with advantage, and as in this case the expansion would be $1\frac{1}{3}$ times, the total initial

pressure required would be $\frac{86.96 \times 1.33}{1 + \text{hyp. log. } 1\frac{1}{2}}$ $= \frac{115.95}{1.288} = 90$ lbs. per sq. in., or 75.3 lbs. per sq. in. above the atmosphere. In this case the final pressure would be $\frac{86.96}{1.288}$ =67.5 lbs. total.

These matters being disposed of, we are now in a position to calculate the quantity of air required for the trip. The driving wheels being 11 ft. in circumference, they will make $\frac{5280}{11}$=480 revolutions per mile, and if we suppose the amount of compression be just sufficient to fill the clearance spaces, there will be thus used for each mile run 480×4=1920 cylinders full of air at the final pressure. The diameter of the cylinders being 4½ in., and the stroke 12 in., the capacity is 0.1104 cubic ft., and during the run of 3 miles on the level there will thus be used 0.1104×1920 ×3=635.8, or, say, 636 cubic ft. at the final pressure of 19 lbs. above a vacuum; while on the gradient the quantity used will be 0.1104×1920=211.96, or, say, 212 cub. ft. of the final pressure of 67.5 lbs. total.

If now we suppose the temperature at which the air is exhausted to be 40 deg. Fahr.,* the weight per cubic ft. at the final total pressures of 19 lbs. and 67.5 lbs. will be 0.1004 lb. and 0.357 lb. respectively. The weight of air used in making the run of 3 miles on the level will thus be 0.1004 ×636=63.854, or, say, 64 lbs.; while the weight used on the gradient will be 0.357×212=75.684, or, say, 76 lbs. The total weight used on the trip will thus be 140 lbs. The capacity of main reservoir necessary to supply this quantity of air will of course depend upon the initial pressure given to the latter, and we may mention here that the higher that initial pressure is, the less will be the gross weight of the air necessary at the commencement of the trip in proportion to that utilized. Thus, for instance, if it is necessary that the pressure of the air in the reservoir shall never fall below 100 lbs, per sq. in. total, and if the initial pressure be but 200 lbs. per sq. in., then it follows that but one-half of the air originally stored in the reservoir can be turned to account. If, on the other hand, the initial pressure be 300 lbs. per sq. in., then two-thirds of the gross quantity of air can be utilized, and so on, it being supposed that the temperature of the air is maintained constant during expansion by heat supplied from an external source. In the case of our example we will suppose the air to be stored at the initial pressure of 300 lbs. total, and the pressure at the end of the trip never to fall below 100 lbs. total, under which circumstances it will be necessary that the reservoir should contain at starting at least $\frac{140 \times 3}{2} = 210$ lbs. of air. At a pressure of 300 lbs. total, and a temperature of 62 deg., air weighs about 1,552 lbs. per cubic ft., and the capacity of the reservoir would have to be at least $\frac{210}{1.552} =$ 137 cubic ft. To guard against losses by leakage, etc., it would, however, be necessary to provide perhaps about 20 per cent. greater capacity than this, or say 170 cubic ft., in which case a reservoir of the requisite size might be of 34 lengths of wrought-iron tubing, each 10 ft. long by 9⅝ in. diameter inside.

We now come to the final question which has to be considered here, namely, what is the amount of heat which it will be requisite to supply to the air to compensate for that rendered latent during expansion? In dealing with the question we shall for the present neglect the slight difference between the initial and final temperatures (namely 62—40=22 deg.), and shall suppose the reduction of pressure to be caused by increase of volume only. If the *absolute* temperature (that is to say the temperature in degrees Fahrenheit+461.2) of any quantity of air at a given volume V_1 be represented by T_1, then the absolute temperature, T_2, of this quantity of air when expanded to the volume V_2, will be $T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{0.408}$. When the engine taken as our example is running on a level, the air is discharged at a total pressure of 19 lbs., while the pressure in the reservoir is 300 lbs., and the relative volumes on the supposition already stated would be as $\frac{300}{19}$:

* In dealing with the pressures in the cylinders, it was assumed that the air was maintained at a constant temperature, and it may at first sight be deemed that this is inconsistent with the air being exhausted at a temperature of 40 deg., while the initial temperature in the reservoir is taken subsequently at 62 deg. In reality, however, there is no such inconsistency, as the reduction of temperature from 62 deg. to 40 deg. may take place between the reservoir and the cylinder, and it is, in fact, to a certain extent, preferable that it should take place at that point, as the lower the temperature in the cylinder the greater is the facility afforded for the transmission of heat to the air from external sources.

1=15.7 : 1. The initial temperature being 62 deg. Fahr., or 461.2+62=523.2 deg. absolute, the final temperature would, if no heat was supplied from an external source, be by the formula just given : $T_2 = 523.2 \times \left(\frac{1}{15.7}\right)^{0.408}$. The 0.408th power can be readily calculated by the aid of a table of logarithms, and we then have $T_2 = 523.2 \times \frac{1}{3.076} = \frac{523.2}{3.076}$ 170 deg., as the final absolute temperature. The fall in temperature would thus be 523.2—170=353.2, or, say, 353 deg., and in order that the air might be exhausted at the same temperature at which it left the reservoir it would be necessary to supply to it from external sources as much heat as would raise the temperature of the weight of air passing through the cylinders 353 deg.

We have, however, supposed the exhaust to take place at 40 deg., or 22 deg. below the initial temperature, and the heat to be supplied from the hot water jacket, or other source, while the engine is running on the level, will only be that requisite to raise the weight of air used 353—22=331 deg. The weight of air used in passing over the level portion of the line being 64 lbs., and the specific heat of air being 0.238, the heat required for this portion of the trip will be 331 deg.×64×0.238=5042 pound-degrees.

Proceeding in the same way for the portion of the run made on the gradient, we find the relation between the initial and the final volumes to be $\frac{300}{67.5}$: 1, or 4.44 to 1; and the temperature, T_2, thus becomes $523.2 \times \left(\frac{1}{4.4}\right)^{0.408} = 523.2 \times \frac{1}{2.073} =$ 252.3 deg.; and the fall of temperature, supposing no heat to be supplied, would thus be 523.2—252.3 =270.9 or 271 deg. Deducting, as before, 22 deg. for the lower temperature of discharge, we find the amount of heat required when the engine is mounting the gradient to be that necessary to raise the quantity of air used 271—22=249 deg. The weight of air used on the gradient being 76 lbs., the heat required will be 249×76×0.238=4504 pound-degrees.

The total quantity of heat to be supplied to the air from the hot-water jacket throughout the whole trip is thus 5042 +4504=9546 pound-degrees, and, if we suppose the water to be allowed to fall in temperature but 30 deg. only—say, from 200 deg. to 170 deg.—the quantity of water which it would be necessary to carry in the jacket would be but 318.2 lbs., or, say, 32 gallons. In order to allow for imperfect circulation, the quantity requisite in practice would have to be greater than this; but in all probability a supply of 50 gallons at an initial temperature of 200 deg. would be ample to insure the maintenance of the requisite temperature of the air throughout the trip.

The present article has extended to such a length that we have no space to speak of the mechanical details to which it would be requisite to give attention in carrying out the mode of working compressed air engines which we have been describing. These points, however, we may possibly touch upon on some future occasion. Meanwhile we may state that it must be borne in mind that the employment of compressed air for working an engine cannot be regarded as an economical mode of utilizing power, as an important loss of effect will in all cases ensue, from its being at present practically impossible to turn to account the heat generated while the air is undergoing compression. Notwithstanding this, compressed air affords a means of transferring power which is capable of doing good service in many situations, and it is therefore well worthy of the attention necessary to ascertain the best mode of turning it to account.

NICKEL MINES.—Attention is being called to the nickel mines of the country, which promise handsome returns for their development. The only such mine at present practically worked is in Eastern Pennsylvania, and is highly remunerative. In Missouri, one mine was worked from 1850 to 1855 on the Mine-la-Motte tract. The ore was the sulphuret, associated with lead and copper. About $100,000 of nickel was realized from mining the croppings of this vein. "Outcrops" of this ore are also found in Madison, Iron and Wayne Counties, Mo., but none are worked at present, as we are informed. The refined metal is worth about $3 per lb., and for many purposes supplants silver.

THE CAUSES OF EARTHQUAKES.

(*Continued from page 544.*)

6.—HOW THE EARTHQUAKES ARE PRODUCED.

Let us take it for granted that, owing to the living activities of the earth, a considerable quantity of these necessary chemical elements have collected, and that the waters of the sea having percolated and saturated them, a very active chemical action has taken place and evolved a considerable amount of calorific.

This will soon reach the incandescence, particularly if the point where the chemical action is taking place happens to be in contact with the voltaic arch formed by the electro-magnetic current passing between the sun as positive element and the earth as negative. This is precisely what has occurred on the 13th of August, 1868, in the southern provinces of Peru, and three days later in the northern of Ecuador.

It is a fact worthy to be noted, that the great and destructive earthquakes have always taken place at the time of some eclipse of the sun or moon.

The moment a single atom becomes incandescent, irradiation takes place, and the surrounding atoms soon attain the same degree of heat as the first, the inciting causes being incessantly at work. From this focus of irradiation, caloric will extend from one molecule to another; and it will not be long before a large subterranean furnace will be in existence.

What will then happen? It is perfectly obvious that the water existing in the neighborhood will be converted into steam, and this constantly overheated into gases, which by their enormous dilatation will exert a tremendous pressure against the wall of their place of confinement.

Everybody is now acquainted with the force of expansion of gases. In their action on the superficial strata we shall find the explanation of earthquakes.

These gases must find an issue. They press against the crust above in a perpendicular direction. This crust happens to be sufficiently resistant, composed of homogeneous materials that render it elastic—upheavals then take place, like those observed from the remotest antiquity to our times. All these upheavals are always preceded by earthquakes, with emissions of sulphurous vapors and sulphuretted hydrogen gas, smoke, etc.

If the crust is not sufficiently resistant, a new crater is opened, a volcano is formed. These are the boils on our mother earth's body, that having ejected all the matter contained in them, subside and even disappear. We have an example of this phenomenon a few miles from Granada (Nicaragua) in the volcano of Musalla, which has completely vanished since the conquest by the Spaniards, and the place where it stood is now a level plain covered with burned and blackened stones.

Let us suppose that the superstrata are homogeneous, and so resistant as to withstand the enormous pressure of the immensely dilated gases. Then the soil will be convulsed, tremendously shaken; and the mighty works of men destroyed, levelled to the ground.

As deep as man has penetrated in the superficial strata of the planet, he has found them honeycombed; traversed in all directions by moats, conduits, caverns and hollows, which contain large deposits of water, forming lakes and pools, originating subterranean currents, streams and rivers.

These moats, conduits, caverns, etc., etc., are separated by walls more or less thick. These walls in the vicinity of the furnace, being less resistant than the crust above, give way under the pressure of the gases; an issue is opened for their escape. They precipitate themselves into it with incommensurable force; hence the rumbling noise—the thunder-like explosions which always accompany earthquakes and precede them by a few seconds, giving warning of their coming.

By the falling of the walls of the caverns and moats, the props of superstrata being destroyed, these cave in; hence the abasements of the surface, the rendings, the disappearance of some streams, the appearance of others—the changes that take place in the configuration of the countries where the catastrophe has occurred.

The gases, in their onward rush, meet other openings; part precipitates into them. Soon they expand on a larger

field; their forces, not being any longer concentrated, grow less and less as they find more avenues through which to escape; and as they are further from the centre of their generation, that is to say, from the furnace. Many of these furnaces, no doubt, exist, that having communications with active volcanoes are not perceived on the surface; or have a vent in the shape of Geysers, hot springs, mud volcanoes, etc., etc. The hot well discovered at Lacrosse, Wis., in the month of February, 1868, when some men were boring an artesian well, bears witness of the truth of my assertion.

The upward pressure against the ceiling of the conduits, accounts for the waters in the wells overflowing, and for the changes of their level. The sulphurous nature of the gases accounts for the fetidity observed in subterranean waters, in caves and cellars.

Different and very distinct motions of the soil have been noticed during earthquakes. They are easily accounted for.

The most common is known under the name of *undulating motion*. It may be explained in this wise.

The walls and ceilings of the subterranean cavities are rugged and uneven, resembling somewhat the waves of the ocean during a gale, with more or less deep indentations; they are not composed of the same and homogeneous materials. In places they are more resistant than in others; and when gases come from a long distance, and somewhat disperse, they do not exert their power with so much force on the ceilings. They consequently give rise to a motion similar to that felt on board of a vessel at sea, and called for this reason *undulating motion*.

There is a second motion called *sussultaria*, eruptive. This has been observed many times, and always accompanied by great catastrophe.

Such motion, foreshadowed by sulphurous vapors, occurred during the months of February and March, 1783, in the plains of Calabria and Mesina, when the tops of granite hills were clearly seen to jump up; the stone foundations of houses, even the pavement in the streets, were so lifted up as to be found turned upside down.

The city of Riobamba was destroyed by one of these eruptive motions in the year 1797, and the bodies of some of the inhabitants thrown on the top of a hill 100 ft. high.

Palmeri and Scachi, in their report on the earthquake of Melfi, which occurred the 4th of August, 1851, expressly say, that columns were broken at the base without losing their perpendicular position; that chimneys were heaved up into the air, falling again in their natural place.

The city of Mendoza was destroyed in 1861 by a motion of that kind.

The ceilings of the furnace, being homogeneous and resistant, will not swell or upheave, but sustain the shock occasioned by the puff of the gases incessantly arising, dilated from the focus of heat, in the same manner as the steam escaping at intervals through the escape pipe. The perpendicular shock is repercussed to the surface, in the same manner as if you give a sharp blow under a table; the table, to be sure, will resist, but the objects on it will be thrown up into the air.

The third motion (moto vorticoso) is rotary or circular. Many doubt its existence; but I see nothing that can be opposed to it. We read in the papers an account of the earthquake that was felt in the year 1868 in San Francisco, California, and a motion of that kind is said to have been observed in the lower part of the city.

After the earthquake that occurred in Valparaiso in 1822, three palm-trees, placed at a short distance from each other were found intertwined, and so have remained ever since.

It is also reported that after the earthquake of 1783 in Calabria, two square obelisks placed in front of the Convent of St. Stephano del Bosco, were found turned round on their pedestals. Many other cases, similar to those, are reported, proving the existence of the rotary motion.

But, how is such motion to be explained?

In two different manners. Have you ever noticed how a rotary motion can be imparted to a small metallic wheel, supported on a steel or iron axle, on which it can revolve freely, merely by rubbing vigorously with a rough file one end of the axle? If so, you have seen it turn of itself as it were in the same direction as the file is drawn.

Why would not also a powerful stream of gases, rubbing against the rugged ceilings of the conduits, produce a strong

electro-magnetic current, that would impart a rotary motion to the objects on the surface, in accordance with the laws that govern currents of induction.

Again, this rotary motion may be explained in this wise.

When two currents of air, coming from opposite directions, meet each other, they give rise to a whirlwind. If these currents are very strong, a hurricane or tornado is the result. Well, there is no reason why the same phenomenon, which takes place above ground, should not also occur under ground, when two different current of gases, coming from opposite directions, meet in the interterrestrial passages and cavities.

Nature works in the same manner in all its manifestations when the conditions are equal. Similar causes produce like effects; then two currents of gases meeting under ground, will produce a tornado; and a rotary motion will be imparted to all objects within its boundaries.

I have reviewed in a very cursory manner all the effects produced by the convulsions of the earth, and, by the synthetic method of reasoning, tried to arrive at the understanding of their causes. I have not advanced an opinion, which is not founded on *facts* acknowledged by science, on events recorded in history. I do not propose any theory, but merely give in these few lines the result of my own observations and investigations. If they satisfy your mind, as they do mine, then I am happy, for I have attained the object I had in view when I took the pen.

Let me then recapitulate, and sum up in a few words my

7.—CONCLUSIONS.

1. There is no central fire. It is unphilosophical, unscientific to uphold the opposite doctrine—for it merely rests on speculations, unsupported by facts and science. It must therefore be disregarded by all scientific minds.

2. The heat of the earth has its source: 1st. In the friction occasioned by its rapid motion through the cosmic matter that fills all space. 2d. In the rays of the sun, that, however cold in themselves, carry light that, setting in motion the molecules of the atmosphere, generates heat, which is communicated to the earth. 3d. In the constant chemical decompositions that are incessantly going on in its great interior laboratories. 4th. In the oxidation of the metallic substances that compose the superficial strata of the planet. All these phenomena are produced by the agency of electro-magnetism, which seems to be the life sustainer of the whole creation.

3. The volcanoes are not the safety valves or vents of a central fire, which does not exist; but are merely local accidents produced by a conglomeration of materials, sulphur being one of the principal, that, being soaked by salted waters, enter into chemical decomposition, under the agency of electro-magnetism, and that the volcanoes are to the surface of the earth what boils are to the surface of the human body, which disappear as soon as the matter accumulated is expelled.

4. That the sun's immense reservoir of electro-magnetism, and the other celestial bodies, which are likewise reservoirs of the same agent, increases the action of the electro-magnetic currents that traverse the earth, according to their respective positions with regard to this, and hasten the effect of the chemical operations, if a point of the voltaic arch formed by them comes in direct contact with the place they are going on on a large scale.

5. That earthquakes and volcanoes stand in intimate relations, have a common origin, and will ever occur in those places where large chemical action is taking place. That inasmuch as chemical action is alive in every part of the earth, earthquakes may be felt on any point of its surface.

6. That the origin of earthquakes may be found in the expansion of gases generated by the various causes enumerated, particularly chemical decompositions. These gases, being prodigiously dilated, press heavily against the wall and ceilings of the cavities in which they are confined, and in trying to find an issue through which to escape, produce the dreaded phenomenon.

7. That when a volcanic action is going on in the substrata of the surface of the earth, and earthquakes are impending, the phenomenon is foreshadowed by many precursory signs.

8. That among these forerunners the following are the most evident: 1st, sulphurous vapors arising from the ground in the vicinity of the focus of the chemical action; 2d, strange and mysterious noises,

produced by the activity of the gases; 3d, alterations of the mineral waters, occasioned by the percolation of the gases through the porousness of the superficial strata, and affecting its chemical compounds; 4th, turbidity of the fresh waters in wells—phenomenon produced by the same causes; 5th, changes in the level of the waters in wells, caused by imperceptible upheaves and depressions of the superficial strata, affecting the sources or subterranean streams which feed them; 6th, emanations of carbonic acid or sulphuretted hydrogen gas, perceived in cellars, caves, wells, excavations; 7th, electro-magnetic disturbances in the atmosphere, suddenly taking place and without any apparent causes, manifested by the loss of power of magnets.

10. That the opinion of Plinius, the elder, commends itself to the serious consideration of all men of science : that the evil consequences of earthquakes might in some measure be arrested by boring deep artesian wells in the countries subject to earthquakes, for those wells would act as vents through which the gases might escape, and their raging storm partly quelled.

A few years ago, 4 deep wells were discovered, one at each corner of the cathedral in Lima, which had been destroyed by the earthquake that laid that city to the ground in 1687. The church was rebuilt and these wells bored to act as protectors of the monument. They have well fulfilled their duty, for the edifice has withstood all the different shocks that since that epoch have visited the capital of Peru, and destroyed many of its strongest structures.

8.—CATACLYSMS OF THE 13TH AND 16TH OF AUGUST, 1868.

These cataclysms are some of the most terrible known in the history of mankind, as much for the ravages they have occasioned, as for their duration and the extent of country they have visited, spreading dismay and consternation, death and ruin among the inhabitants. Beautiful and densely populated cities have been levelled to the ground, flourishing seaports swallowed by the sea, whole towns together with their dwellers have disappeared into the bowels of the earth.

In Peru the shock was felt over a radius of 1,670 miles. In Ecuador, 43,000 human lives were destroyed in a twinkling of the eye.

The centre of the earthquake of the 13th appears to have been the volcanic zone comprised between Arequipa, Tacna, and Moquegua, where are situated six volcanoes—the *Cailloma*, the *Misti*, the *Ubinas*, the *Huaina-putina*, which made an eruption on the 13th of February, 1600; the *Tutupaca* and the *Candarare*.

The focus of the second, that of the 16th, in Ecuador, was in the volcanic fields of Ocampo, surrounded by the 3 volcanoes, the *Cotacachi*, the *Imbabura*, the *Pasto*.

The prefect of Arequipa, Dr. Francisco Chocano, in his report to the Secretary of State, says : That on the 13th of August, at 5.15 P. M., a very severe shock of earthquake was felt in Arequipa, when within 5 minutes the whole city was levelled to the ground. The oscillations, from S. to N. E., shook the soil with tremendous violence during 7 minutes; they came accompanied by *gushes of air charged with electricity*; the motion of the earth was such as to make it next to impossible to keep a firm footing or remain standing. *The soil heaved up and fell as the surface of the sea during a gale. A sudden obscurity spread over the city, adding* to the horrors of the event. *The waters became muddy in an instant.* During the night of the 13th, 35 shocks were counted, but the soil was in continuous motion. *Loud detonations were heard every instant and in rapid succession,* like the rattling of musketry during a battle. *Rents were opened in the earth; sources sprang forth through them* so abundant as to inundate many places ; others have sunk and disappeared. The shocks continued at intervals. The Misti *sent forth enormous columns of smoke* in the midst of horrid detonations.

Such were the events of that memorable afternoon of August 13, 1868, that were witnessed by the inhabitants of Arequipa.

All these phenomena I have reviewed and tried to explain are effects of volcanic action. Arequipa is built on the slope, nay, at the very foot of the Misti, and has at periods nearly equidistant been destroyed.

On the 2d of January, 1582, an extremely severe earthquake shook that city to its very foundations ; another, equally terrific, occurred in 1587 ; then another,

in 1590, that laid to the ground the city of Camaria, an immense tide wave invading the ground, inundating the Peruvian shores; again, on the 18th of January, 1600, when the volcano Huayna-putina made an eruption; again, on the 25th of November, 1604; again, in 1605, when the city of Arica was destroyed; again, on the 13th of May, 1647—the shock was that time felt along the whole coast; again, on the 22d of August, 1715; again, on the 6th of February, 1716—day of the destruction of the city of Torata; again, on the 27th of March, 1725—this earthquake shook the whole southern coast, and the port of Callao was submerged by the sea; again, on the 13th of May, 1784. I merely mention these earthquakes as they are the most important, passing in silence hundreds of others of minor intensity, that at short intervals have occurred, warning the inhabitants of these regions, that under their feet was a focus of electro-chemical action, whose living activity continually threatened their existence.

Commandant Thomas Layseca, of the forces stationed at Torata, informs us that the earthquake was felt at 5 P.M., lasted 12 min.; and that from the 13th to the 15th, date of his official report, 600 shocks had taken place.

In Tacna, on the 13th of August, a *grand oscillatory motion* of the earth occurred at 5 P.M., lasting 5 min. At that place, for several days previous to the 13th, *subterranean noises were heard, and some light shocks felt.* When the earthquake occurred the day was cloudy, and shortly after it began to rain (a strange phenomenon in a country where it never rains), to the 16th of Aug., that is, during three days 64 vibrations, accompanied with subterranean noises, were felt; large and deep rents opened on the surface, and gushing through the openings. In Palea and La Portada, on the road to Bolivia, the shocks were most violent. *Large portions of hills became attached,* and rolled down the valleys– *the mountains being split open with frightful noise.*

I will call your attention to the fact, that in this place the motion of the earth was different from that at Arequipa, being *oscillatory,* instead of *undulating,* as it was at the latter place; notwithstanding its violence at both places, being such that men could scarcely keep their footing, the results were quite different. The strongly stone-built city of Arequipa was levelled to the ground, while in Tacna only 40 houses were destroyed.

This fact would tend to show that the oscillatory motion causes less ravages than the undulating.

Again, the premonitory symptoms of the impending catastrophe were distinct, but passed unheeded.

Electro-magnetic disturbances took place also in the atmosphere, causing rain to fall—an occurrence which seldom or ever takes place in this part of the country.

In Chocorento, a village in the valley of Acari, the earthquake took place at 4.30, destroying all the houses in the valley. The shocks succeeded each other in rapid succession; the sea rose mountain high, and ran inland one and a half miles; all the watercourses became dry; the ground opened in many places, and *water gushed up* through the fissures in large bubbles; *continuous noises,* resembling the roaring of cannons in a battle-field, were heard incessantly.

It would seem that the phenomenon manifested itself at this place 30 min. in advance of the other localities; but this is evidently an error of computation of time on the part of the observer; for this valley is in close proximity to the other places.

In *Moquequa,* the earth began to shake at 4.45 P.M., five minutes in advance of Arequipa and Arica, about 90 miles to the southwest of the former city. There the vibrations were always preceded by *electric discharges,* louder than the heaviest cannonading; were from east to west, alternating with *vertical shocks,* and succeeded each other with frightful rapidity during 5 to 6 min. The hills of limestone were split, the rocks rent in small pieces. The soil opened, and through the openings issued streams of *blackish and pestiferous water.*

With *Arequipa* and *Moquequa,* the city of Arica is that which has suffered the most. Situated on the sea-coast 40 miles to the southwest of Tacno, it is the most important port of Peru, next to Callao.

At 5 P.M., a very severe earthquake was felt on shore, says the commandant of the ill-fated frigate America, which was stranded that day. "All the houses in the city surged, and with an ominous crash fell to pieces; then the earth was seen to open,

a *rolling, rumbling noise* was heard, *and gases, stifling gases,* emanating from the fissures, soon filled the atmosphere, severely oppressing all living creatures, causing them a sensation of suffocation. The shocks lasted 10 min., and succeeded each other at short intervals, and were accompanied with subterranean explosions. The hills themselves were seen to stagger like intoxicated beings. Large boulders, detached from their brows, rolled down their slopes, while their sides were seen to give up the dead bodies of the Aymarcis, that for centuries had been intrusted to their safe keeping, and had so long peacefully slept in their solitary resting-place, the slumber of death. These mummies seemed to have emerged from their graves, as if to witness the convulsions of mother earth ; and their lifeless mouths appeared to laugh, exhibiting gumless rows of white teeth, at the terror of the living seeking refuge in open places, and flying to the top of the high lands for their lives.

The shocks came from the south ; the skies were stormy, a very light wind blew from a southerly direction. The whole soil of the country, as far as it could be seen, was moving ; first like a wave, from north to south, then it trembled, and at last upheaved heavily.

During that time a very *strong current from the south set in* in the bay. The current was so strong as to set adrift the boat of the frigate America, sent to shore for the commandant, notwithstanding the efforts of the crew. It measured 5½ miles an hour, lasted 5 min. Then came a *second current* from the opposite direction; this left the bay nearly dry.

Currents, now from the north, then from the south, succeeded each other with great frequency, and became so rapid as to make it impossible to send boats to rescue the people who were seen floating on the palisade and imploring help. The frigate began to drag her chains and anchors. At 6.45 P.M. the currents increased to 9½ miles, their duration being from 5 to 10 min. ; at 7.5 P.M. a current came from the south, its rate 10½ miles. Then the sea began to retire slowly from the shores, leaving the boats dry. It receded about to the line of extreme low tide, when at once it rose again and invaded the land. It reached a height of 34 ft. above high-water mark, overflowed the town, and destroyed everything that the earthquake had left standing. The waters rushed back in the ocean, and rose again to the same height as before. Several times did the advancing waves wash over the doomed city ; several times the force of the waters carried all the debris of the ruined habitations of men, until at last, retreating about 2 *miles,* it returned as an immense wave 50 ft. high, carrying the frigate America more than a mile beyond the railway tract, in a place called *Chinchero,* and the American ship Wateree about a mile further up the beach.

Eleven tidal waves occurred, the intervening time between each invasive wave was 3 min., the third invasion having occurred soon after the first, and the last and largest 20 min. after the first.

At Iquique the earthquake lasted 5 min., the sea rose 30 ft. above its ordinary high-water mark, and covered the town to the extension of 600 ft.

At Ilo, north of Arica, the sea retired, leaving the ships completely dry, and rising again in a wave 40 ft. high washed away all the houses and everything else.

At Islay the waves obtained also an altitude of 40 ft. over their natural level, and covered 3 times the wharf without doing much injury. The town, being built on the summit of a very high cliff, escaped destruction.

Caracas, a small landing place near Jisco, was swallowed by the sea, and the boats that were in the bay carried away and left two miles inland.

In Callao the earthquake was felt at 4.46 P. M.. It came with an *oscillatory motion*—a motion similar to that of a boat in calm weather; it lasted 10 min.; at 6.30 P. M. another shock was felt, of 5 min. duration. A few minutes before 7, high-water was to take place. The water, instead, began to recede; at 10.30, for the first time, the water reached a higher level than it was ever known to have attained before, within the memory of man; at 11 a tremendous wave, 18 ft. high, invaded the land to upward of 600 ft. from the beach; currents set in from opposite directions at a velocity of 3 to 4 miles an hour; at the time a soft breeze from S.W. blew, the atmosphere was perfectly clear.

These are, in as few words as possible, the phenomena that were noticed during the terrible cataclysm of the 13th of August, 1868; the greatest, perhaps, on rec-

ord, with that of the 16th of the same month, which visited the province of Imbabura during our historical period.

Following the great tidal wave which originated on the coast of Peru, on its way across the Pacific, and taking into account that the difference in longitude between Arica and New Zealand is approximatively 9 hours, we shall find that the wave having reached the New Zealand coast at 6 A. M. of the 15th has employed 29 hours to travel 6,120 miles. Its velocity may, therefore, be computed at 211 miles per hour. Its violence, even then, was extraordinary. The Island of Chatham to the eastward suffered greatly, for the wave that struck it was of such magnitude as to completely destroy the colony of Tupinga on the North.

The tidal wave reached Hokodadi (Japan) at 10 A. M. on the 15th, presenting itself by a series of waves that caused the sea to recede and be depressed until 3 P. M. under its level, and rise again above it with great velocity. During 10 min. per watch a difference of 5 ft. was measured; the constant elevation and depression of the tide at that place being only 2½ to 3 ft.

It reached the Sandwich Islands on the 14th at 8.46 P. M., and continued to manifest itself during the 14th, 15th, and 16th, by a series of waves, rising and receding 3 to 4 ft. every 10 min.

From these data a comparative table showing the time employed by the tidal wave to reach the different places may be thus formed:

PLACES.	GREENWICH TIME.			LOCAL TIME.			
	Dates.	H.	M.	Dates.	H.	M.	
Peru	13	9	40	13	5	..	P. M.
Sandwich Islands	14	2	6	14	3	46	A. M.
New Zealand	14	7	6	15	7	..	A. M.
	14	13	6	15	10	30	A. M.

Fifty-six hours after the ruin of Arequipa and other cities of Peru, another terrible cataclysm visited the northern provinces of Ecuador. The volcanic fields of Ocampo seemed to have been the focus of the electro-chemical action whose effects culminated in the destruction of 40,000 human lives, and the ruin of the cities of Otabalo, Ibarra, Atmitaqui, Catacachi, Perucho, San Antonio, San Pablo, and many smaller towns and villages besides part of the city of Quito, the ancient capital of the Seyris, or Kings that governed the Empire of Quito, before its conquest by Huayna-Capac, and the modern capital of the Republic of Ecuador.

Quito, built on the slopes of the volcano Pichincha, is elevated 9,500 ft. above the level of the ocean. Several times it has suffered from the eruptions of the Pichincha since the conquest, the most remarkable being those that occurred in 1575, 1587, and 1660. The cataclysm of the 16th of August seems, however, to have been the most disastrous that has afflicted these regions, the most volcanic known on the globe. Here are found grouped on a plateau about 200 miles long by 80 broad, a great many volcanoes, which, for the most part, at different epochs since the conquest, have given the most unmistakable proofs of activity. The Chimborazo, the Cotopaxi, the Pichincha, the Altar, the Illinaza, the Corazon, the Cayambé, the Riobamba, the Sangai, and many minor ones, are here gathered nearly within sight of each other.

The earthquakes that visite Chili, Peru, Ecuador, and California, withen the five days that elapsed between the 13th and 19th of August, notwithstanding their synchronism, did not originate from the same centre of action. Each had a distinct focus, to which a greater activity was communicated by coming in contact with some of the points of the voltaic arch formed, in those days, by the relative positions of the sun, moon, and earth.

In Quito meteorologic disturbances occurred on the 15th: heavy showers of rain and hail, and heavy thunder; at 1.20 A. M. of the 16th a severe shock of earthquake was felt, then the earth continued to shake at intervals to the 19th. All the principal churches were levelled to the ground.

In the district of Catuchi two towns were totally destroyed without leaving a trace of having existed. The town of Atmitaqui was destroyed; in that of Ibarra, the capital of the province of Imbaburi, 13,000 persons perished; rents were opened and closed, huge pieces of rocks were seen tumbling down the sides of the mountains, hills sank, carrying with them sugar-cane plantations, houses and everything on them. That where the city of Otavalo was built, sank and was replaced by a lake. Where Cotacachi once stood is now as wamp; large quantities of stones were hurled from the Cotacachi; from the Imbaburu issued a torrent of mud, the flow of which was followed by that of water; from the crater of the Ocampo were ejected large quantities of bituminous matter. The Sangai was seen in a state of constant eruption. Dark clouds of dust and a heavy rain of fine powdered earthy matters fell; a total darkness prevailed and covered the country as a pall, the obscurity of which was illuminated at intervals by flashes of light from the volcanoes, amidst continuous detonations that resembled the roaring of a distant cannonading.

Resuming all these data, I came to the conclusion, that the production of these phenomena had its origin in 4 different centres of action. Those felt in Peru had for centre the country between Moquegua, Arequipa and Arica, encircled by the 4 volcanoes—the Misti, at the foot of which is situated Arequipa; the Huayna-putina, the Ubinas, and the Tutapaca, forming part of the chain of Cordilleras immediately behind Moquegua.

2. The earthquakes that shook the greatest part of Chili seems to have originated in the volcano of Leullallco, situated 240 miles from Copiapo. It was reported to have broken out in a violent eruption, its crater vomiting lava, ejecting large stones; the ground at the base of the mountain opened in numerous places, and through the rents spouted forth currents of water impregnated with sulphuretted hydrogen gas; these occurred on the 14th and 15th of August.

3. The earthquakes that destroyed the northern parts of Ecuador had their centres of action in the fields of Ocampo, and in some of the numerous active volcanoes that are strewed all over the great plateau of Quito. They took place on the 16th of August.

4. The earthquake that occurred the 16th of August in San Francisco and various other places in California, had probably their origin among the numerous volcanic fields that are so frequently met with in that country; and their centre of action may have been the same that has produced lately the earthquakes of Sacramento, Inyo, and other places.

THE NEW ZEALAND FLAX.

From "Journal of the Society of Arts."

A report of the Flax Commission, appointed to investigate the preparation and the relative value of the *Phormium* fibre, or New Zealand flax, has ben printed, in which the microscopic structure and chemical composition of this plant, together with its market prices and general use, as compared with Irish flax and Russian and Manilla hemp, are set forth. It appears that there are several flax-mills at work in the colony, varying in their efficiency and the quality of the article produced; but that room yet remains for further improvements to be effected. The first duty undertaken by the commissioners was to visit the chief districts where *Phormium* fibre is prepared, and to inquire into the different processes of manufacture. The tables of the Registrar-General had shown that, during the year 1870, there were 161 mills in operation, with an aggregate of 342 stripping machines, employing 1,450 horse-power, 1,766 persons, the produce being 4,457 tons of fibre; but several proprietors had closed their mills at the time of this commission, in consequence of the fall in the value of the fibre. The inspection by the commissioners, of the mills then actually at work, proved that throughout the colony one almost universal method of manufacture is adopted, with the view of producing fibre for rope-making. The green leaves are stripped by revolving rollers with projecting beaters, travelling at a high rate of speed, which crush the

epidermis against a fixed plate so set as to allow room for the fibre to remain intact. The fibre, thus freed from the leaf of the plant, is washed by various methods, put on the ground or on lines to dry and bleach, finished by an arm or barrel-scutch, and when baled is ready for the market. No material alterations in the manufacturing processes have been made, but a more skilled labor and enlarged experience have improved the general quality of the fibre, so that it is more eagerly competed for in the London market, as approaching nearer the appearance of Manilla hemp, and is in fact capable, in the opinion of competent judges, of being so prepared as to surpass it. The chief improvement, recently introduced, is the wet-scutching, by which the fibre is cleaned and softened, although it has not always been commercially successful, for, whilst local purchasers were ready to give £3 per ton extra for the flax, the loss of fibre by formation of an excessive amount of tow, and the additional expense of labor, increased the cost from £6 to £10, so that the new process was abandoned; but, notwithstanding this, the commissioners strongly recommend it for further trial. The mills are chiefly worked by steam power, and good streams of water are also essential for the effectual washing of the fibre, which, when carefully prepared and neatly baled, fetches as much as from £17 to £21 per ton, although the ordinary price is about £15. The cutting of the flax leaves is an important point. In some fields an established vigorous plant, in suitable soil, will yield four good leaves for manufacture every year. The leaves are usually of twelve months' growth, and vary from 3 to 5 ft. long. In some parts they are greatly injured by a small "looper" caterpillar, about an inch in length, which eats quite through the fibre, in patches from a half to two inches, and a quarter of an inch broad. This insect comes to its full size, and is most numerous, in the month of December. Of the leaves, when cut 5½ tons yield one ton of fibre. They are mostly found after two years' growth to have passed their prime, and begun to decay. The green strippings of the leaf form food for the horses. Extensive areas, covered with wild *Phormium* plants, leased from the natives, with abundance of water at hand, and labor at a moderate rate, render some of the mills highly profitable. They, of course, vary in their value, and improved plans of scutching, setting, rolling, and washing, with other important points in the process, are occupying the attention of the manufacturers generally. The commissioners state that more life and enterprise in respect to the fibre industry are to be found in Canterbury than in any other province. An interesting question has been raised as to the relative durability of the *Phormium* fibre rope. It is discovered that the New Zealand white rope, when kept dry, will last longer, and wear 60 per cent. better, than tarred rope of the same material, and 34 per cent. better than Manilla hemp rope, although this last is found to be actually improved when wetted with salt water, in consequence, it is believed, of the shrinkage—equal to 5½ per cent—which takes place, whilst the effect of the salt water on the New Zealand rope reduces its lasting qualities 34 per cent. The *Phormium* rope of Canterbury, when oiled, is proved to possess a great power of resisting wet. Plain New Zealand rope, constantly in the water in a Californian pump, was found to last not more than seven or eight days; Manilla rope would run for twenty days; but a piece of the oiled New Zealand rope did not give way till it had been 95 days in continual wear. For heavy work and running gear, the fibre has been so successfully treated, being divested of the gum and otherwise strengthened, as to become, in the estimation of many, more valuable than Russian or Manilla hemp. From samples carefully collected by the commissioners, the breaking strains of a large portion have been determined, and it is shown that the strength of the several descriptions at present exported varies from 53 to 84, with an average of 69, as compared with Manilla, which is taken as the standard at 100. On the other hand, the samples of native-dressed fibre ranged from 70 to 122, with an average of 91. In the northern and central districts, the quality of the fibre thus tested has been best, but in the south there is a marked absence now of those inferior qualities which once created an unfavorable impression in the home markets. There has been a classification of fibres, according to the manner in which they are cleaned and freed from

scull, and also in reference to their color and texture. Such terms as "mixed in color," "harsh," "wiry," "poor color," "green and brown," "red ends," "croppy," "coarse," "rough," "much straw," and "heeled," are of frequent use, and indicate differences in value to the extent of several pounds sterling per ton. It is also mentioned that the sisal fibre, which is obtained in Yucatan from a species of aloe, is the only kind that will compete with the *Phormium* as a substitute for Manilla. The native-dressed *Phormium* appears to be the finest, but it has been found almost impossible to obtain any large supply of it. It may be interesting to add, that there are several kinds of this peculiar fibre, differing chiefly in their color, especially of the edges and mid-rib, and that the growth of the plant in its earlier stages is exceeding slow. It is, moreover, found that the varieties are most surely perpetuated by sub-dividing the roots. The structure and mode of growth of these roots show that a true under-ground stem is formed with fibrous rootlets, which stem, after a growth of several years, with a succession of leaves, bears a flower stalk, and then decays; but it also, during the period of its growth, gives off lateral buds, from which new fans proceed, acquire their own roots, and finally become independent plants, clustering together, and forming unusually large bushes. In propagating the plant, these lateral fans, as soon as rootlets have been formed, may be removed and transplanted in the same way as tubers, and will be vigorous in proportion to the amount of nutritious matter which has been accumulated in them. It is not yet certain to what extent the repeated cutting of the leaves for manufacture affects the development of the flower stalk, the increase of the root, and the formation of the new fans. And, indeed, the normal growth of this plant is a matter still surrounded with doubt. It is difficult to say what its full value may be, since maturity is not attained until after several years, so that the system of taking the leaves after two or three years' growth is no real test of its capabilities, and on this account the commissioners do not recommend its cultivation on an extensive scale, more especially as there is more than a sufficient supply of the raw material to meet a much larger demand than at present exists. Manufacturers prefer the *Phormium* that grows on high or dry ground, as it is purer, and more easily stripped than that found in swamps. There appear to be as many as 55 varieties of this plant, as distinguished by the natives, but it is believed that 20 marked varieties are all that can be accurately defined. The commissioners feel confident that *Phormium* has now acquired a permament hold on the market at a remunerative value, and that past failures have arisen, not so much from any fault inherent to the plant, as from want of experience. It is where there have been labor at a moderate rate, abundant raw material, and water for motive power and washing, that the fibre has been produced with the largest amount of profit. In every case, minute care and constant attention are requisite for the production of the finest descriptions and qualities of the fibre. The commissioners summarize the information they have collected by referring concisely to the chief points in the manufacture of a good quality of fibre. The selection of the leaves, which should have from 14 to 20 months' growth, and their careful preparation, is a matter of prime importance. Care must also be taken that the machinery be kept clean and in perfect adjustment. The washing of the fibre, after it has been reduced to finely-divided bundles, is essential, to secure excellence of quality, but long soaking is to be avoided, as tending to make the fibre soft and cottony. The rolling is advantageous when the washing has been completed, as it consolidates and defines the bundles, and the bleaching and drying which follow should be effected with rapidity. Scutching is the next step in the process, which, where the former parts have been efficiently carried out, should be performed rather with the view of burnishing the fibre than of reducing the quantity, by the production of a large proportion of tow. The use of oil is found to improve the appearance of the fibre, and also reduces its liability to undergo further maceration in water. It is best applied as the final stage of the scutching. The animal oil used by the natives is pronounced to be the best, and superior to the application of tar, which has an action on the fibre like that of acids. With respect to the baling, wire or hoop-iron is condemned. Scrim or

other light cloth is in general favor for this purpose. The use of the plantain leaves for the Manilla bale suggests that the New Zealand fibre might be economically and safely baled in coverings made from its refuse leaves. The dimensions, also, of the Manilla bale are recommended. It measures 3 ft. 3 in. by 1 ft. 8 in., by 1 ft. 8 in., and weighs about 2¼ cwt. The commissioners urge that the name "phormium" should be adopted for this New Zealand fibre, as avoiding misconception, and being more in keeping with the names applied to the other roping fibres with which it has to compete in foreign markets.

The following tables are taken from the commissioners' report:—

From April, 1870, to May, 1871.

	Bales.
In five distinct qualities brought to public sale in London	36,008
Sea-damaged	87
Tow	1,546
	£. s.
Total value, reckoning 6 bales to 1 ton	140,506 0
Average price	23 8

	Relative Durability and Wear.					
	Circumference before experiment.	Circumference after experiment.	No. of days run.	No. of feet run at 4,575 per hour.	No. of miles run.	Durability per cent.
	in.					
Dry:						
Manilla	1.43	1.25	20	915,000	173 3	100
New Zealand (white)	1.56	1.25	28	1,281,000	242 6	134
" (tarred)	1.56	1.34	15	686,250	129.9	74
Wet:						
Manilla	1.43	1 12	22	1,006,500	190.6	110
New Zealand (white)	1 56	1.18	20	915.000	173.3	100
" (tarred)	1 56	1.34	19	869,250	164.6	95

It is hoped that a method of preparing the fibre before shipment, that will soften and divide it sufficiently fine to make it suitable for the manufacture of textile fabrics, will be ultimately crowned with success.

A FRENCH ARCHITECT ON THE ARCHITECTURE OF THE SECOND EMPIRE.

From "The Builder."

Frenchmen, naturally more emotional than ourselves, are more given to import their emotions into their business affairs. Since the downfall of the Napoleonic dynasty, and the crushing disasters which followed it, little has been publicly spoken or written in France on any subject whatever without an ultimate reference to the woes of the country and their supposed causes, or without an anathema hurled against the invader. The architects of France have, naturally enough, proved no exception to this rule. In grave-side orations they have added a political lament to the expression of personal sorrow, and in written disquisitions they have endeavored to cast odium of failure on the shoulders of the *régime* under which they recently flourished. One of the latest architectural opponents of the Second Empire is M. Daniel Ramée, and his strictures have been admitted, under reserve, into one of the Parisian professional journals. The charges which he brings forward are numerous, and expressed in no measured terms. Many of his *confrères* differ from him; but many also agree with him, and in order that our readers may understand the views of those French architects who look on the darkest side, we translate a portion of his lengthy tirade. He says :—

During the eighteen years from 1852 to 1870, Paris and many other towns in France have completely changed their aspect. The venerable monuments which recall the national traditions and memories and glories of the past have been gravely marred and mutilated, cut down, and hacked about,—have even been thrown to the ground to make way for edifices of no intrinsic artistic merit. Moreover, a deplorable change has gradually taken place in the public taste, and particularly in architecture. There has, perhaps, never been an epoch which is richer in resources and materials of all kinds; and never in any epoch or among any people have public works absorbed a larger amount of the public money. Yet there has never been a people who, with so vast means of execution, have produced such paltry results, or results so sad and regrettable.

The degradation in which architects lay under the feet of the Second Empire arose from two principal causes:—first, the equivocal and pernicious management of new architectural schemes; and second, the thoroughly bad and insufficient education given to students destined for the architectural profession. It is of the first alone that we shall speak. Under the Second Empire everything was sacrificed to the consolidation of the throne of Napoleon, and in pandering to the depraved tastes of those who helped to establish it. Under that Empire architecture, like the other arts, was abandoned to intrigue, and partially to baseness, to masterly incapacity, to confusion, and to disorder. And architecture itself was without unity, without knowledge of its lofty purpose, without sincerity, without healthful fancy, and last of all without that elegance which is one of its chief attractions. All these faults arose from the absence of a capable, enlightened, independent, sagacious, and really national supervision. The ministry of Public Works was awarded by chance, by favoritism, or through the influence of those in Court favor, and was at the mercy of vain and inflated cliques, who utilized the power of office to carry out their own whimsical and fantastic caprices. Hence naturally emanated those servile and often burlesque conceptions in which oddity and frivolity predominate, in which a meagre and foolish fancy prevails, and which are marked by degeneracy of taste and a want of suitability to the times,—in short, which, while seeking to derive inspiration from the masters of the art, only succeed in bringing forth hybrid works without character; which are displayed, too, with impertinent assurance and stupid satisfaction before the public, in whom they excite little interest and still less admiration. For the real non-official public looked with a cold and indifferent eye on those edifices which cost it so dear, which it saw surcharged with blunders and inconceivable artistic liberties, and which are but bad imitations of the styles of the past on their decadence. This public was, moreover, disgusted with the boastfulness which thought to impose on enlightened and independent spectators; it was astounded at the audacious presumption which outraged and violated it, which provoked and annoyed reflective people, and which excited the contempt of all true artists.

The more we regard the architecture of the eighteen years of the Second Empire the more does it appear insipid and inconsistent. The works produced during that time are only an eternal reproduction of academic types, which have been stereotyped for years, and which it is fatiguing to encounter without variation on every occasion.

To pile stones on stones, mouldings on mouldings, columns on columns, to fill deformed niches with second-rate statues, or to raise them on pedestals and entablatures, to leave no blank space in the elevations, but to cover them over with debased profiles and sculptures of doubtful merit, to add ornaments which are of no conceivable use in the positions which they hold, except to mislead the eye, and detract it from the weakness and poverty of the architectural composition, has not resulted in the production of a real work of art, and has only given satisfaction to the vulgar and the interested creatures of the Empire, but never to those animated with a love of what is suitable and beautiful and true. The First, like the Second Empire, suppressed liberty, and used its every energy to hasten the national decadence, so that it might establish its own absolutism. The intellectual tone has been lowered, and all creations of the imagination have been less bright and glorious. The Arts were stranded in the universal shipwreck in which our military

glory foundered. With very rare exceptions, the buildings of the Second Empire, tricked out in the unintelligent gaudiness of the *parvenu*, and hurried up with so much precipitation, reminds us of the structures of Augustus and of Constantine. To produce works quickly and abundantly, to prefer quantity to quality, seem to have been the device of these princes—and notably of the former—to consolidate their dynasties; and the Second Empire has not failed to pursue the same course with the same end in view.

RAILROADS IN PERU.

By. F. J. CISNEROS.

Written for Van Nostrand's Magazine.

During the Presidency of Don Juan A. Pezet, in 1864, the Peruvian Congress passed a bill promoting the construction of easy and speedy railroads, for which, in addition to other subsidies, an annual interest of 7 per cent. during the period of 25 years, was also granted to any company that would untertake the construction of railroads at their own expense.

Many causes prevented the execution of these plans until 1868, when the President was authorized to make contracts for the construction of railroads "to Arequipa, Puno, and Cuzco; from Chimbote to Santa or Huaraz; from Trujillo to Pacasmayo and Cajamarca; from Lima to Jauja; and to all other places where they are needed."

Colonel José Balta, then President of the Republic, has until now endeavored to carry out the provisions of that bill, with the greatest energy, and he has succeeded beyond public expectation. So they have now in Peru 28 railroads, some of them in a working condition, some in process of construction, and the rest already nearly finished.

They are the following:

From Arequipa to Puno	232	miles.
" Arica to Tacna	39	"
" Callao to Oroya	130	"
" Chancay to Cerro de Pasco	120	"
" Chimbote to Huaras	172	"
" Eten to Ferrenafe	28	"
" Huacho to Sayan	36	"
" Ilo to Moquegua	63	"
" Iquique to Pena	45	"
" Iquique to Noria	37	"
" Lima to Callao	8½	"
" Lima to Chancay and Huacho	89	"
" Lima to Chorrillos	7	"
" Lima to Magdalena	3	"
" Lima to Pisco	145	"
" Malabrigo to Ascope	28	"
" Mollendo to Arequipa	107	"
" Cerro de Pasco to Pasco	15	"
" Pacasmayo to Guadalupe	14	"
" Pacasmayo to Magdalena	69	"
" Paita to Piura	63	"
From Pisco to Ica	48	miles.
" Pisagua to Sal de Obispo	35	"
" Juliaca al Cuzco	209½	"
" Salaverry to Trujillo	10	"
" Tacna to the Bolivian frontier	108	"
" Tacna to Puno	301	"
" Trujillo to Eten	148	"

The whole length of these roads is 2,310 English miles, or 3,716.80 kilometres, of which about 500 kilometres were in operation at the end of last year, viz.: from Eten to Chiclayo, from Lima to Chancay, from Lima to Callao, from Lima to Chorrillos, from Pisco to Ica, from Mollendo to Arequipa, from Tacna to Arica, from Iquique to Norria, from Lima to Cocachacra, and from Cerro de Pasco to Sacrafamilia.

Many local exigencies have prevented the completion of all these lines, but every body in Peru understands the advantages of having a net of rails throughout the territory. Peru possesses extensive forests with valuable timber, rich mines and fertile lands, separated from the coast by high mountains, making the transportation of their productions so expensive that nobody considers them as an element of productive trade. Of course, railroads will develop all these riches, and will pour them into the foreign market.

The railroad from Tacna to the frontier of Bolivia, will be very useful to this State, a country so abounding in mineral and vegetable wealth. Some foreign speculators have undertaken the construction of this road and the Peruvian Government will give about $6,000,000, the third part of the capital needed.

Bolivia will also profit, through Lake Titicaca, by the construction of a railroad from Arequipa to Puno.

All these projects, when carried to execution, will considerably increase the pros-

perity of Peru, and will finally communicate by connecting the interior lines, the shores of the Atlantic with those of the Pacific Ocean. Until now nothing has been made to connect the interior lines, but the communication with the Atlantic would be an easy undertaking by prolonging the Lima and Oroya railroad to Acobamba, Fuerte, San Roman, and Maïro, hence to the confluence of the River Pachitea and Ucayali. From this river to the Amazon, navigation is very easy.

Another way of reaching the Atlantic would be by the prolongation of the Juliaca and Cuzco railroad. Urubamba river, which passes near Cuzco, is not easily navigated from Mision to Mainiqui, but from here to its mouths many travellers assure us that navigation is entirely safe. Between Cuzco and Mainiqui there are 210 miles; both places being united, the southern part of Peru will have an easy communication with the Atlantic. We are almost sure that both projects will be carried out, although great expense must be incurred on account of the obstacles of the surface because that part of the country possesses many valuable riches, and Bolivia needs that communication for her foreign trade.

Besides, the enterprise of constructing a railroad from Lima to Oroya, and from Puno to Cuzco, is in the hands of Mr. Henry Meiggs, and he, knowing the advantages of such communications, will undoubtedly conquer, with his indefatigable energy, every obstacle that would deter many another enterprising capitalist.

The name of Henry Meiggs is connected with the most important enterprises in Peru. Besides the construction of the above-mentioned roads, the Government has authorized him to construct the railroads from Mollendo to Arequipa, from Arequipa to Puno, from Ilo to Moquegua, from Pacasmayo to Magdalena, from Pacasmayo to Cajamarca, from Pacasmayo to Guadalupe, and from Chimbote to Huaraz.

Mr. Meiggs has not confined himself to railroad enterprises. He is now superintending the building of 1,000 houses on the ground where the walls of Lima were once erected. He has asked also permission to establish a line of cars around that city.

Peru has sufficient resources to carry out the most expensive projects, as can be seen by the following statistics of her imports and exports:

	Import.	Export.
From Callao yearly	$24,000,000	$48,000,000
" Iquique "	4,800,000	7,200,000
" Arica "	6,500,000	3,156,245

The principal article of exportation is the *guano*, of which are exported through Callao 500,000 tons, valued at $20,000,000.

According to the statistics published in Lima, in 1868, 7,175,195 tons of *guano* were exported from the 19th of February, 1842, to the 31st of December, 1867. Total value, $218,693,625.

Besides *guano*, a large quantity of nitrate of soda is yearly exported through Iquique. The exportation of this substance increases daily, and in 1870 amounted to 147,205 tons, the value of which was $8,832,000.

The incomes and expenditures are as follows:

INCOME.

Guano	1,181,327 tons,	$44,915,451
Duties on export		4,818,000
" on import		229,600
" on tons		246,000
Tax on real estate		195,300
Duties on patents		185,900
" on stamps		374,100
" on mails		123,100
Other incomes		7,895,400
Total		$58,982,751

EXPENDITURE.

Interior police	$6,460,004
Foreign affairs	490,043
Justice, public instruction	4,632,333
Army and navy	10,870,762
Finances, commerce	4,812,564
Payment of public debt on public works	30,729,058
Total	$57,913,764

Leaving a surplus of $1,069,087.

Although many new expenses have been incurred since the publication of these figures, Peru still has sufficient means to carry into effect all her important enterprises; her resources are inexhaustible; new ones are daily discovered.

The railroads are developing the riches of the interior provinces. In the department of Ancachs, where they are now constructing a railroad from Chimbote to Huaraz, the land produces every kind of fruit; gold, silver, and copper mines are found there, and it is assured that coal is also found there in large quantity; this article, imported from England, at present being very dear on the Pacific coast. Thus

the working of the mines in that department will greatly increase the revenue of Peru. This country needs only peace and easy communications to furnish the world with many precious and valuable articles.

May everlasting peace give to her enlightened population the means of developing industry and commerce, and that part of our American continent will be, in the course of a few years, a centre of activity and an emporium of nature's choicest riches.

NEW YORK, *February*, 1872.

COTTAGE BUILDING IN NORWAY AND SOME OF ITS TEACHINGS.

From "The Builder."

In the present state of things architectural, so confused, and with so much that indicates a fast-coming change, it must be not a little interesting to inquire into the work and methods of work of those who have *not* had, as we have, vast heaps of arts "precedent" to go by and to copy. It is not a little singular to reflect on that it has been reserved for these modern days to be so entirely at the mercy of what has gone before. In no other age of the world has the architect of the *then present* been at the mercy of that which preceded it. It never would seem to have copied,—always followed or seconded. Each age or generation took up the work as left by those who preceded it, improved on it or not, as the case might be, and so, in effect, left behind them practically a new style, a growth out of that which preceded it. It did not copy or make effort to reproduce what had gone before, but simply went on with the work, and, by degrees, worked out a new style. Nothing can show this more convincingly than the primitive system of hut or cottage building in Norway,—*i.e.*, in those parts of it removed from the influences of modern and new systems of construction and new and patent materials. The subject is a curious one, and worth a little consideration and inquiring into, if only as a primitive system of doing things before style commenced, and before any one ever thought of copying. How to build architecturally and artistically, without any architectural precedent—in other words, to build up mere material constructively and ornamentally,—is an important question. It has been contended that this cannot be done,—that some definite architectural forms and ornament are absolutely necessary; and that these are the work of time and growth, and that no "architecture," in its full meaning, can come out of mere and simple construction; but it is a little wonderful to see, if you look a little below the surface, how much of architecture is to be found in the simply and rudely constructive. Before we go further, it is not a little to be regretted that no trustworthy system has as yet been invented of rendering wood *fire-proof;* for the want of it, and the consequent disuse of timber construction, have thrown wood-work into the background. No wooden houses, where any sort of building art prevails, are now possible, so that timber-house construction and fine art are of the past. This is to be regretted. A complete history of wooden house-building and architecture with wood only for its material, is to be gathered in Norway alone; indeed, this history may be said to go back beyond the historic era, for there are evidences of wooden buildings on piles, of a date far beyond written records. Architecture grew up here and there, doubtless, out of materials and simple and necessary construction, each separated nationality or race having its own.

But the main practical interest of the subject lies of course in the strictly modern plan of hut or cottage building, as it exists, and as people now live in such buildings. Of course we are speaking only of the purely *native* system of building proper to the country, and not of that which is gradually superseding it, and which has been borrowed from foreign sources. These cottages are formed of pine logs, but roughly squared, with the sharp edges cut off so as to be nearly octagonal. These logs are laid one upon another, and with a layer of moss between them in lieu of mortar. The logs forming the side or end walls are notched, so as to

receive the ends of the timbers forming the front and back walls. Each log is from 12 in. to 13 in. or more square, so that the walls are about a foot thick. The walls are about 10 ft. high. In the better sort of cottages the whole of the interior of the rooms are lined or panelled, so that it would be difficult to discover a better system of building, or one more entirely suited to the climate. A warmer kind of walling could not be devised, nor one more "comfortable" in appearance. The floors and ceilings are boarded, the former, raised from the ground by stone sleepers, a foot or two high. We hardly know what will be said about the *roof;* but why should a clever thing be lost sight of? Improvement of course is introducing *slate*, always neat, if not genteel; but the poor old Scandinavians look to warmth and comfort, and perhaps to harmony and picturesqueness, if not to the "architecturesque;" and they covered their rough roofs with close boarding, then with birch bark peeled off in flakes; and then on this they laid earth about 3 in. in depth, retained by a fillet running along the eaves. A crop of moss of course soon covered this earth, so that a more picturesque or better colored roof could not be, or a warmer or better heat-protector or keeper-out of cold. The joiner's work is but rough, like the walls and roof, but all harmonizes, and may truly boast of one good quality—it keeps out the wind and the weather! Surely such a system of building as this is as good as can be for the place it is in, and for the surroundings of rude forest and rapid watercourses and lakes. Some might think this a better way of building a cottage than the thin-walled and meagre model cottage, which is, says a good authority, but "the skin of a house." The old Scandinavian and his not yet thoroughly civilized modern successor think nothing does but the solid timber logs between them and the cold. Nothing, indeed, can be more *comfortable* than the interior of one of these wood-walled and wood-lined rooms. With the prosperous Scandinavian there is always a room for everything, for the material being so plentifully supplied by a bountiful nature, there remains but the trouble of building and putting together. Many of the houses are two-storied, and the stairs, from the ground to the upper story, are sometimes singularly quaint and architectural. Now, this is an old-fashioned way of work, and rough as may be; but we may ask, what workman is there that would not sooner live in such a tenement than a in patented, thin-walled, and corrugated iron roofed model-house of the most recent make and pattern, and choke-full of scientific inventions and improvements?

It will thus be seen—at least, to some small extent—that in this far northern and somewhat out-of-the-way country there now exist materials for forming some idea as to the origin if not creation of a style of architecture, the growth out of mere *constructional necessity*, and out of the materials afforded so abundantly by nature on the spot whereon it has grown up. We cannot in looking at it avoid the pressing thought of how much light is thrown analogically upon the origin and progress of Gothic architecture in these islands, for both are the results of Northern thinking out and requirements. We say "Northern," and use the word in place of a better, and as descriptive of the doings artistically and architecturally of a people distinct from Southern and Eastern races. It leads us, too, to the much-vexed question, now especially interesting, of how far is it possible to *invent* an entirely new style of architecture? Is it possible to create a new style of architecture to be founded on, and to grow out of, simple and necessary construction? and can it be accomplished in *one* age, or even so far carried on in one as to show itself as a something distinct in that age, and will the study of all other styles help or hinder it? No small amount of discussion might be raised on such a revolutionary project, and without something to go by,—"precedent" of some sort or other. There are some who might even go so far as to say the thing is impossible in the very nature of it. One thing, however, this Northern work undoubtedly shows, and it is this, that art and architecture may grow out of bare construction with "precedent," or a something to go by, entirely absent. This simple architecture harmonizes perfectly with the scenery and surroundings of the place it fills. There is no jarring element in it. As to the modern transplanted villas and smart houses, you wonder where the latter came from, and who could possibly have imported them, so fearfully do they put out nature,—the na-

ture which surrounds them,—a primeval forest growth, nature's own work, and which, as it would seem, man cannot without more capital and science destroy. What a pity it is that "improvement" has not stayed its hand here and there, and left us a town or even a small village from the old days,—some small collection or group of houses, whereon no disturbing artistic element would be found, with its quaint inn, irregular streets of houses, so truly "picturesque,"— its small church, and all those other little quaint things, once upon a time to be seen everywhere. A litle of this, as all know, is to be found here and there, and the antiquary and the architect have ransacked England to find them out, and to transmit them to posterity on paper; but the things themselves are fast disappearing, and must soon be numbered with the things that were. But in Norway these strange things are yet to be seen, and a curious light indeed they throw on things architectural and artistic.

VERTICAL ENGINES FOR THE NAVY.

From "The Engineer."

The engines in our iron-clad ships break down so frequently that their incessant failure begins to cause much uneasiness among engineers. It is no new thing for a marine engine to break down, but until within the last few years the thing broken was almost invariably the crank shaft. This species of casualty has, however, become more and more rare, as better materials and improved methods of manufacturing them have been adopted. We scarcely ever hear in the present day of the breakage of a screw shaft in our navy, and the reason is obvious. Not only are these shafts very well made, but they escape the deteriorating influences continually operating in the mercantile marine. In other words, they do so little continuous work that the metal of which they are made is not fatigued. The distance run under full steam in any one year by any one of our iron-clads is excessively small; it is as nothing, indeed, when compared with the service got out of the engines of any large full-powered screw steamer carrying mails, passengers, and cargo. The principal casualties to which our naval engines are liable are almost unknown in the mercantile marine. They consist in the splitting of cylinders and condensers, and they recur with the most alarming pertinacity. We have seen why it is that the crank and screw shafts of our iron-clads last very well. It remains to be seen why the rest of their machinery is not equally permanent; and we have reason to believe that this question is now receiving the most anxious consideration from at least one eminent firm of marine engineers. We have already expressed our opinions on this point; but the enormous importance of the subject, which affects the efficiency of our navy quite as much as any question connected with guns or armor-plating can do, is a sufficient excuse for returning to it again. We start from this point with two propositions. The first is, that the principal cause of the splitting of cylinders—to say nothing of certain other casualties of far less importance—lies in the horizontal position of the engines. The second proposition is, that in iron-clads it is unnecessary to to adopt the horizontal type. We have so fully and recently discussed the first of these two propositions* that we shall only allude incidentally to it now, and devote our attention principally to the second point—namely, the feasibility of using vertical engines in our navy.

Very early in the history of steam navigation it became evident that in war ships it was essential that engines and boilers should be kept well below the water line. The Amphion, engined by Messrs. Ravenhill, Salkeld & Co., was the first ship the machinery of which complied with this condition. Up to the time of the Russian war paddle-wheel war steamers were actively employed, but ever since no choice has been left with the marine engineer. He has been compelled to keep his machinery below the water line, and a very great stimulus has, therefore, been given to designers of horizontal engines. As the art of defending ships with armor plates progressed, however, greater scope was afforded to the marine engineer for carry-

* Vide The Engineer for January 19th and February 2d, 1872.

ing out his views, and the necessity for keeping all machinery well down in the ship grew less and less. A prejudice in favor of the horizontal engine for war ships was, however, unfortunately established, and to this day, although the necessity for seeking protection below the water line has long since passed away, engineers still adhere to the original practice and put engines for the navy on their sides. If we glance at the history of the screw engine in our mercantile marine, we find that at one period horizontal engines came into fashion. They were in favor for her Majesty's ships; and as the the best possible engines, it was assumed, found their way into the navy, private shipowners could not do better than adopt the same type. The desire to have horizontal engines in merchant ships did not last long, however, and for several years nearly all the marine engines used in our merchant service have been of the vertical type. There are a few exceptions to this rule, of course, but they are too rare to affect the question materially, if at all. Now, it is certain that our great steam shipping companies know perfectly well what sort of machinery answers their purpose best, and as they are wealthy, considerations of cost stand little, if at all, in their way. If, then, the vertical type is used, almost to the exclusion of the horizontal type, in very large steamers intended to be always ready when wanted, and to be as free as possible from the chance of break-down, why should the gentlemen who supply engines to our navy adhere blindly to the horizontal type virtually rejected long since by the shipowning community? The necessity for using the horizontal or low type of engine passed away as soon as armor plating assumed importance; and it is almost, if not quite, certain that machinery is safer in the present day behind 6 inches of plating than it can possibly be below 6 ft. of water. If it is deemed necessary to plate our ships far below the water-line, then it follows that the water cannot give sufficient protection until we arrive at a point considerably below the lower edge of the armor plating; but no one dreams of applying this rule to the marine engines of our navy. Indeed, it would be impossible to keep them down far enough in any ship. Therefore we already depend upon armor plating for their protection. Why not carry the principle a little further, and, relying wholly on the plating for protection, adopt that form of engine which is most suitable for the intended purpose?

It may be argued that the space taken up by vertical engines would be too great, but this is contrary to fact. Such engines really occupy less useful space than any horizontal engine; the place occupied by the upper portions of the machinery usually being left totally unoccupied. In ships of war as well as merchant vessels, it is essential that there should be a good roomy hatchway—in other words, that there should be a portion of the deck next above the engine-room floor cut away—for the purpose of securing ventilation and light to the engine-room. In this space could stand the cylinders or guides of a vertical engine; while in our war ships of great beam much valuable space now taken up by the engines would be rendered available for stores, or even coals. It must also be borne in mind that the stroke is in modern screw engines always short, 4 ft. 6 in. being the maximum. Great power is had by running pistons of enormous diameter at a very high velocity, but the height of an engine is measured by the length of stroke, and therefore it will not do to urge that, although vertical engines of 450-horse power nominal may be got into a reasonable space measured vertically, yet that it would be impossible to do the same with engines of double the power. As a matter of fact very small engines may take up just as much height in a ship as engines of the largest size. So long as the length of stroke is kept within moderate limits there is no danger that the engine will be too high.

As to the kind of vertical engine to be adopted, that must be settled by the conditions which will obtain in each particular case. The return piston-rod engine, set up on end, will be the best under some conditions, the inverted trunk engine under others. We are not prepared to advocate the adoption of very large engines of the steam-hammer class, as the great weight of the cylinders may act prejudicially in such cranky craft as some of the recent additions to the navy. But no marine engineer of experience will meet with the least difficulty in designing perfectly safe and trustworthy vertical engines capable of indicating 6,000 or

7,000-horse power, provided he has all the space allowed him which a great iron-clad can legitimately place at his disposal. We may add that in our opinion it will be found far better in the long run to get these excessive and abnormal powers out of three or even four cylinders of moderate dimensions than out of two only of colossal diameter. There should be no difficulty in expanding steam five times in a four-cylinder engine, each cylinder giving out, say, 1,000 to 1,200-horse power, and the expansion beginning and ending within it. The balance would be perfect, and the strain on the crank-shaft extremely uniform. It is probable, too, that the cost of such an engine would be slightly less than that of an engine with only two huge cylinders, difficult to cast and to handle; and while the chance of a breakdown would be reduced with the diameter of the cylinders, so it is clear that even if one engine did break down, the ship would still remain efficient so long as the the other three engines were uninjured, which would not be the case with any of the ordinary double-cylinder marine engines. If it were determined that engines of the compound type must be adopted, then, probably, the best results would be had from an engine consisting of three vertical cylinders, disposed side by side, the two small cylinders standing fore and aft of the large cylinder, and exhausting into a receiver from which it would draw its supplies. Each of the three cylinders would, of course, work a separate crank, set at such an angle with its fellows as to secure the maximum regularity of motion.

THE LIME PROCESS CONSIDERED WITH REFERENCE TO THE PRESENT STATE OF THE SEWAGE QUESTION.

From "The Building News."

The employment of lime for the clarification of sewage water was, in all probability, suggested by what is known as "Clark's process for softening water." Carbonate of lime (the usual source of hardness) is soluble in pure water to the extent only of about two grains per gallon, though it is found freely dissolved in what are termed "calcareous waters," owing to the presence in them of carbonic acid, which acts as a solvent. When this gas is expelled (as, for instance, when the water is boiled), the carbonate of lime held in solution through its agency is deposited, resulting, in the case of steam boilers, in the formation of the so-called "scale." The plan of softening water devised by Dr. T. Clark consists in the addition to it of a slight excess of milk of lime, which, by combining with the free carbonic acid, occasions a precipitate of carbonate of lime. This precipitate carries down with it the carbonate of lime previously held in solution by the acid, in the form of fine crystals, together with any coloring or organic matter which may happen to be present. The water is thus rendered, in the course of a few hours and at a very trifling expense, perfectly bright and clear.

Sewage water, which may be regarded as water containing fram 50 to 150 grains per imperial gallon of mineral and orginic impurities, lends itself admirably to such a system of purification as that which has just been described. On the addition to sewage of from 2 to 42 grains per gallon, according to its strength (by which we imply the amount of the impurities in it), of slaked lime, a bulky precipitate is formed, which entangles the floating particles of organic and solid matter, and as it gradually settles, leaves the supernatant water perfectly clear, and, to a considerable extent, deodorized. The above treatment constitutes what is known as the lime process, and this plan of dealing with sewage, in spite of Dr. Clark, has been several times patented, and partly perhaps on account of its simplicity, and partly because of its cheapness, seems to have been always a favorite one with sewage experimenters. It has more than once been carefully investigated by Royal Commissioners, and the relative advantages and disadvantages arising from its use have formed the subject of considerable differences of opinion.

It may be as well, before going any further, to glance briefly at those printed reports upon this process which are avail-

able, among the more important of which we may name that of Messrs. Hofmann and Witt, forming Appendix 1 to the Report on the Metropolitan Drainage, 1857; Professor Way's Report on the Deodorisation of Sewage, being Appendix No. 6 to the Second Report of the Sewage of Towns Commissioners, 1861; and the remarks upon the treatment of sewage with lime, vol. 1, p. 52 *et seq.* of the First Report of the Rivers Pollution Commission, 1870. In connection with these, we may examine also the Report of Dr. Letheby, forming Appendix No. 4 to the Report by Messrs. Bidder, Hawksley, and Bazalgette on the Main Drainage, 1858.

When, in 1856, certain referees were appointed to investigate the main drainage of the metropolis, it was deemed essential at the outset of the inquiry to ascertain the value of sewage, and the practicability of utilizing it. Dr. Hofmann and Mr. Witt were accordingly requested to furnish a report upon the subject, which they did under date of July 1st, 1857, and the information thus obtained may be said to have laid the foundation for all subsequent estimates, not only of the value, but also of the possibility of successfully utilizing sewage. Among other processes for the treatment of sewage, these gentlemen paid considerable attention to the plans adopted at Leicester and Tottenham involving the use of lime, and for several reasons, which we may now proceed to examine, they rejected it as unsuitable for the metropolis.

It is almost unnecessary that we should here pause to explain that we possess in sewage a very valuable manure, and that all the precipitation processes aim not only at the removal from the sewage water of its impurities, but also at the production from the solid residue of a sal able manure. Now when Messrs. Hofmann and Witt came to examine the dried residue from the lime process, they found that in lieu of being a valuable manure the deposit contained only one-twelth part of the fertilizing materials present in one ton of guano, and hence they argued that the farmer would have to cart on to his land and spread 12 tons of the lime manure to produce an effect equivalent to that obtained by employing one ton of guano. It was very easy from this to prove that beyond an area of two miles from the works the extra expense of cartage and spreading would do away with all profit on this manure. When, further, it was shown, firstly, that in the effluent water, after the liming, there remained two-thirds of the valuable ingredients of the sewage; secondly, that neither the lime nor any other precipitant removed the whole of the soluble organic matters, which were especially liable in hot weather to undergo putrefaction; and, lastly, that the estimates of the probable cost of the process were based upon insufficient data, it may readily be imagined that their opinion was unfavorable. They, however, admit, in an extract from their report printed as a foot-note to page 22 of the report of the referee—which is not, strange to say, to be found in their report as given in the appendix—that "If we were asked to select one of the processes as particularly calculated to furnish satisfactory results, we should certainly give the preference to the lime process." In the course of their observations, they state that the quantity of the soluble organic matters found in the river after admixture with the sewage, is very minute, and they give no reasons for their subsequent statement, and the one upon which they ground their principal objection to this process—namely, "that the fluid run off from the sewage deposit might very seriously affect the river."

From a careful consideration of their experiments, we have little hesitation in affirming that they did not give the lime process a fair trial, though their results, as far as they go, are otherwise very satisfactory and conclusive.

The sewage water selected by them for the purpose of precipitation by means of lime and taken from the Northumberland sewer, was very concentrated; that is, in one gallon, or 70,000 grains, it contained no less than 160.09 grains of suspended and dissolved matters. To each gallon of sewage water 20 grains of "common gray Dorking lime" were added, after being carefully slaked. Now, Dorking lime is burnt from the lower chalk, and rarely contains less than 10 per cent. of silica, iron, and alumina, and frequently much more. If we assume that the lime used by Messrs. Hofmann and Witt had this percentage of clay, we find that they would thus get only 18 grains of pure lime capable of taking hold of the acids

in the sewage. For this purpose the quantity named would be wholy insufficient, and the precipitation would therefore be incomplete. That such was the case there can be but little doubt, for we are told immediately afterwards that after the lapse of three hours "the supernatant fluid was still opalescent," and that "the whole of the suspended matter had not been completely removed by the process." This description quite tallies with what takes place when the lime used is not, if anything, slightly in excess; a fine granular precipitate is then thrown down, which does not clear the water, and settles only after many hours. But we have other data to go upon in forming our judgment —namely, the amount of the precipitate they obtained.

	Solid constituents originally present.	Composition of supernatant fluid.	Amount separated.
Organic matter.....	88.76	40.34	48.42
Mineral matter.....	71.73	55.68	15.65
Total.....	160.09	96.02	64.07

N. B.—These 64.07 grains doubtless contain the greater part of the 20 grains of lime.

From 160.09 grains of matter in solution and suspension, a precipitate is obtained of only 64.07 grains on the addition of the 20 grains of lime. Further, it seems to us very remarkable that although 20 grains of mineral matters have been added to the sewage, we have only 15.65 grains in the precipitate, and no increase has taken place in the total impurity; for on adding together the grains per gallon present in the supernatant fluid and in the precipitate, 96.02+64.07, we still get 160.09 grains. Here a very probable error, and one which makes a vast difference to all the subsequent calculations founded upon this table, occurs to us. The analysis is headed "Effect of Treatment with Lime (deduced from comparison of analyses of the original sewage with the analysis of the supernatant fluid after separation of the deposit)." From this title it is manifest that, as their results are mere deductions from two independent analyses, the figures 64.07 grains, which are evidently obtained by subtracting the 96.02 grains found in the effluent water from the 160.09 grains ascertained to have been present in the sewage before treatment, do not make any provision for the 20 grains of Dorking lime which were used for the purpose of precipitation. The 96.02 grains in the effluent water should really have been deducted from 160.09+20 grains, giving a residue of 84.07 grains in lieu of 64.07. This latter value is much more like the truth, for if we contrast the analyses of Messrs. Hofmann and Witt with those of other observers, we find that in every case the amount of the precipitate, even when a proportionally much smaller quantity of lime is used, is always over 50 per cent. of the total impurities in the sewage.

In the table on next page we have taken the results given in the reports of the various Royal Commissions, and the engineers consulted by the Metropolitan Board of Works, and so arranged the various calculations as to compare with the amounts obtained by Messrs. Hofmann and Witt. The only case in which lime has been used in considerable excess —namely, to the extent of 42 grains per gallon, is that given upon the authority of Mr. William Higgs, in the Appendix No. 4 B. to the report of the engineers before alluded to. The effect of this quantity of lime upon sewage taken from the same place, and but slightly richer than that experimented upon by the former observers, was the separation from it of a precipitate amounting to no less than 164.4 grains per gallon, leaving litle more than two-sevenths of the solid impurities in the supernatant water in lieu of the residue of three-fifths shown in the case of the previous experiment.

By good fortune we possess a third series of investigations upon the same sewage conducted for the Sewage of Towns Commissioners by Professor Way, which will be found at page 69 of their second report. The sample of sewage water operated upon by him, and taken only a year later, is much weaker than the former ones, containing as it does only 127.3 grains per gallon; but the amount of lime employed, between 15 and 16 grains to the gallon, was also proportionately less. With four grains less lime and much weaker sewage, the precipitate obtained by Professor Way is five grains

in excess of that given by Messrs. Hofmann and Witt; and as the results in this case are not mere deductions, but are founded upon careful analyses taken at each stage of the process, they may be considered, we believe, entirely reliable.

Name of Town or Sewer.	Date when Collected.	Solid constituents originally present.		Total in grains per gallon.	Lime used in grains per gallon.	Precipitate obtained.		Total in grains per gallon.	Percentage ratio of the quantity originally present.	Solid constituents of supernatant fluid.
		Organic.	Mineral.			Organic.	Mineral.			
Northumberland wharf ..	May 16, 1857	88.76	71.33	160 09	20	48.42	15.65	64.07	40.02	96 02
Northumberland wharf	February 3, 1858 .	65.00	108.00	173.00	42	49.80	114.60	164.40	95.03	50 60
Northumberland sewer	March 2, 1859 ...	58.50	68 80	127.30	15 to 16	35.41	34 09	69.50	54.59	71.98
Average of city sewers (day)	May to July, 1857	32.14	61 75	93.89	12	21.06	33.39	54.45	57 99	51 44
" " " (night)	" " "	15.25	63.82	79 07	12	9.90	18 54	28.44	35.96	62.63
Leicester	" " 1856	20.79	85 68	106.47	12?	14.83*	39.31*	54.14*	50.85	64 33
Leicester.....	July 30, 1868	..	..	117.99	12?	40.18*	24.01*	64.19*	54.49	65.80
Average.....	....	..	..	116.29	..	..	..	72 52	62.36	..

* Estimated from effluent water, and analysis of dried mud.

It is not necessary to adduce any other instances, as we think we have said enough to show that the arguments founded upon the above results lose much of their weight when the premises are found to be so fallacious. Many of the calculations of quantity, price of production, etc., are entirely altered by substituting 84 grains for 64.

We have already said that no reasons are given by Messrs. Hofmann and Witt for the opinion they express that the effluent water from the lime process, when diluted with over 200 times its volume of river water, is likely to become a nuisance, and on turning to Dr. Letheby's report, we find that he entirely disagrees with them. Indeed he goes so far as to say, "I am quite sure that the process of defecating the sewage of London by means of lime can be effected with advantage and perfect safety, and the discharge of the clear sewage water into the Thames will not be a source of danger or discomfort to the public."

The report of the eminent engineers who associated with themselves Dr. Letheby is as decisive in favor of the lime process as the referee's report was adverse to this mode of treatment. When speaking of the outfall tanks they say: "The reservoirs are proposed to be constructed so as to enable the precipitation of the sewage matter to be effected by the application of lime. . . . "We can speak positively to the fact that the process is most successful; the water is completely deodorized, as well as rendered bright and tasteless. It does not subsequently become putrescent, though diluted with only twice its bulk of other water." The reason they bring forward against its adoption is the worthlessness of the resultant mud, because, "when produced in large quantities, the precipitated matter is unsalable, and must be removed at considerable expense."

In their second report, the Sewage of Towns Commissioners condemn the process upon similar grounds, though they also allude to the danger there is of the decomposition of the effluent water from this process, when the therein-contained organic substances "are placed under the necessary conditions of temperature, air, moisture, etc." They conclude by stating that "the lime process, though very simple and the least costly of any, is far from perfect," which, as far as concerns the last part of the sentence, may, we fear, be said with equal truth of every plan of precipitation yet proposed. We must defer to another occasion the examination of the remaining reports, and the consideration of the value of the lime-sludge as a manure.

THE SEINE.*

From "Nature."

In carrying out the great works for the improvement and embellishment of Paris under the late Empire, all incidental discoveries of objects relating to art, history, and science, were systematically investigated, recorded, and preserved, instead of being left to the chance and uncertain description of casual and independent observers. In a liberal and enlightened spirit the Municipality of Paris and the Préfet of the Seine, M. Haussman, established a proper organization and a staff (*Service des fouilles et des substructions*) to follow up such discoveries, to take plans of old works, to preserve all art treasures or objects of scientific value; to note, in fact, and to investigate everything of interest. Men eminent in several departments were consulted, and engage to draw up reports with full illustrations of the discoveries. By these judicious measures, the knowledge of the topograpy, antiquities, and archæology of Old Paris has been greatly advanced. Works of the Roman, Gallic, and Mediæval periods have been brought to light, surveys and plans made, and the more important specimens preserved *in situ* or in the public museums.

To M. Belgrand, the eminent and able engineer for the water supply and drainage of Paris, was deputed the work of recording all the geological and some of the archæological facts discovered during the construction of the large works on which he was engaged.

Paris up to the last few years had been supplied with water from local sources (river, canal and wells), but as these were found insufficient and of indifferent quality, it was determined to seek for other and better sources of supply at a distance, and some large springs in the chalk district, respectively distant 60 and 84 miles from Paris, were eventually selected by M. Belgrand, and their waters were brought to Paris by means of aqueducts on a high level. In carrying out this great work, M. Belgrand made himself intimately acquainted with the hydrography of the Basin of the Seine. He explored every valley, and determined the *régime* of every important river. The result of the first part of the inquiry appeared in a valuable series of tables, showing the connection between the rainfall and the discharge of each river—the extent and nature of the floods, and the geological character of the ground with reference to the range and extent of the permeable and impermeable strata, and which he illustrated by a specially colored map. In connection with the construction of the aqueducts, M. Belgrand had also to ascertain the nature of the surface and the contours of the hills and great plains along which he carried them, and to examine the many pits whence the materials for construction were obtained. This geological investigation led to the discovery of many interesting specimens, and further suggested many theoretical inquiries relating to the origin of the present surface, and to the *regime* of the old Seine during the later geological periods. The result of the inquiry is embodied in the three handsome quarto volumes before us—one of 255 pages of text, with 106 pages of introduction, descriptive of the country, and giving the theoretical views; a second containing plates of fossils, of flint implements, and pit sections; and a third with extended colored sections and a monograph by M. Bourguingnat of the shells found in the Drift beds.

Paris stands on Tertiary strata, from beneath which, at a distance of some miles, the chalk crops out and forms a belt many miles in width. These formations constitute a table land having a height of 100 to 200 ft. along the sea coast of Normandy, and rising from 500 to 600 ft. inland in Champagne. This district is traversed by the Seine and its tributaries, flowing in comparatively narrow valleys cut deep into the table land; while on the extended upland plains thus formed, there rise, here and there, ranges of hills of Fontainbleau Sands or other later Tertiary strata. The strike of these hills is in a direction entirely distinct from that of the hill slopes flanking the river valleys and forming part of the present river system. The latter range in various direc-

* From a review of "Le Bassin Parisien" aux Ages Antehistoriques," par M. Belgrand.

tions—north, north-east, south, and south-east—in accordance with the direction of the tributaries of the Seine, until they join that river, the main channel of which has, from Montereau to the sea, a general direction south-east to north-west. M. Belgrand found that the hills on the plains nearly all ranged in this one given direction, or approximately from south-east to north-west, with intervening valleys having the same direction. Numerous such ridges, none being of any great length and all narrow and having this definite trend, are found to extend over the whole plateau area uninfluenced by the more tortuous deeper river valleys which intersect the same area at various angles to their course. The river-valleys are covered with gravel formed of the *débris* of the rocks through which the present rivers flow, while the plateau valleys and plains are free from such *debris*, but are covered with a uniform layer of red clay or loam. Whence M. Belgrand concludes that the two systems of valleys have a different origin. He contends that it is not possible to have a true river channel without having more or less drifted gravels formed by the constant action of running water and by floods, and therefore that these higher valleys could not have been formed by river action, while at the same time their rectilinear and special bearing indicates that their formation is due to one common and independent cause.

M. Belgrand considers that the only explanation which will account for the phenomena presented by these higher-level valleys and hills, is the rapid and transient passage of a large body of water over the surface; and as the excavation of these higher valleys took place after the formation of the Fontainbleau Sands and of the Calcaire de Beauce (Miocene), and before the Pliocene period (for the *Elephas meridionalis* of the valley of the Eure shows that the land had then emerged), and as also, according to M. Elie de Beaumont, the elevation of the main chain of the Alps took place at the same period, M. Belgrand connects the two events and supposes that the sea of the Pliocene deposits of the Alpine area was thereby displaced and that it swept over this northern portion of France, denuding the softer portions of the strata and leaving narrow ridges of the harder portions all trending south-east to north-west (or in the direction from the Alps), standing out, on the denuded high plains, as monuments of its passage. M. Belgrand points out that where the Tertiary strata have presented a resistance which the waters could not overcome, the high-level valleys formed by the diluvial waters are, in such cases, fronted in the opposite range of hills, against which the mass of waters impinged, by a deep bay cut by the current in those hills, and that the waters thus checked in their course were turned off at acute angles, until they reached the main channel of the Seine, tending thereby to form secondary or tributary valleys, which, when the deluge had passed, contributed, with the Seine valley, to form the present lines of river drainage. Such volumes of water as we have depicted would, he argues, have swept the higher channels and plains clear of *debris*, leaving the denuded area covered merely with the silt thrown down from muddy waters, and depositing the coarser *debris* in the middle and lower range of the deeper channels through which the present rivers afterwards took their course. In support of this hypothesis, he shows that, whereas the basin of the Seine is now drained by the one river and its tributaries, the diluvial waters held their course straight across that basin and debouched in five main channels—one, marked by the hills of Montmorency and Satory, took the course of the Seine below Montereau to the sea, but in a more direct and broader line; the second took the course shown by the hills of Villers-Cotterets, thence across the present valley of the Oise, along the valley of the Pays de Bray, to the sea at Dieppe; the third followed in part the course of the Aisne, and then by the line of the Somme valley to the sea; and the fourth and fifth by those of the valleys of the Aulthie and Canche. M. Belgrand accounts for the rapidity and force of this cataclysm in the belief, which he shares with M. Elie de Beaumont, that the elevation of the Alps took place rapidly and suddenly.

But there was a second elevation of the Alps, at a later geological period, and which, according to M. Belgrand, may have produced a second deluge, not by the displacement of the sea, for then there were only lakes on the north-western side of those mountains, but by the sudden melting of the snow on that great range;

and our author again adopts the views of M. Elie de Beaumont on this subject. The distinguished geologist propounded in 1847 the theory that that last convulsion of the Alps was accompanied by an enormous disengagement of those gases to which has been attributed the formation of the Dolomites and Gypsum beds of that chain, and that this caused the accumulated snows to melt in a very brief period of time (*un instant*). At the same time, according to the same authority, the Pliocene lakes of "La Bresse" were raised and drained. Thus, suggests M. Belgrand, this second convulsion might have caused another diluvial wave to pass over the basin of the Seine—an hypothesis also advanced by M. Elie de Beaumont, who speaks of "the probable concourse in this off-throw flood (*deversement*) towards the north-west, of the waters of the great lake of La Bresse, in the production of the diluvial phenomena observed in the neighborhood of Paris."

We are disposed to agree with our author in the opinion, which we have elsewhere expressed, that the original contour of the surface with its higher valleys and hills, is due to a cause different from that which excavated the present river valleys—that it preceded and is independent of it—but we cannot agree with him as to the nature of that cause. Without going far into the argument, we may mention that the well-known fact of the gravel found in each tributary of the valley of the Seine, consisting of the *debris* of those rocks only through which that tributary flows, while in the Seine valley are found the *debris* of all the tributaries, together with its own and no more, is, it seems to us, a conclusive argument against the passage of a body of water from one great basin to another—against the flow of such a body of water from the Alps across the Jura, the great plains of the Doubs and the Soane, the southern prolongation of the Vosges, and, over the separating water-shed formed by the lower hills of Burgundy, to the Seine basin, and so to sea on the northern shores of France. Such a cataclysm must surely have spread the *debris* of the strata destroyed in its course north-westward along the tract over which it flowed. Some remains of the rocks of Switzerland, of those of the Vosges and of Burgundy, must surely have been detected in the course of its passage. How can the author account for the large blocks and abundant *debris* of the Seine valley—which blocks and *debris* he considers as originally due to this cataclysmic action—and yet overlook the almost necessary consequence of the introduction of some foreign elements into the Seine basin, whereas none such exist? Not only is the *debris* of each great basin restricted to its own rocks, but even each tributary valley has its own special rock *debris* and no other. M. Belgrand remarks, it is true, of the Somme Valley, which lies on the line of his third great diluvial water channel, and which prolonged south-east passes across the Oise Valley and up that of the Aisne, that some *debris* of the older rocks of the latter areas have been found in the chalk valley of the Somme. But we must confess we have never found a trace of such a mixture, and we have particularly examined the Drift of those areas with a with a view to the determination of this point. At the same time the water-shed between the two valleys is so low that their complete separation in old times appears to us more remarkable than their present independence, and we can quite conceive the possibility of the Oise waters, when that river flowed at its higher level, passing at periods of flood into the valley of the Somme, and so carrying some small amount of *debris* across the present water-shed, especially as so good an observer as M. Buteux is referred to as the authority for this fact. If there, however, it is evidently quite the exception, and may be accounted for as just suggested.

With regard to the ingenious suggestion of M. Belgrand, that some south-east and north-west valleys of the table-lands are faced on the opposite side of intersecting river valleys by a bay in the hills due to the violence of the checked diluvial waters, such for example as the amphitheatre in the hills on the west of the River Ecolle between Milly and Moigny and again at Soissy, it is to be remarked that such amphitheatres exist equally on the opposite or lee side of the hills towards La Ferté-Aleps and Maisse; and, further, that, in the same Tertiary area beyond the intersecting range of hills between the Ecolle and the Essonne (which according M. Belgrand's views should have acted as a break-water), the south-

east and north-west ridges again resume between the valleys of the Essonne and the Eure.

After the contour of the surface produced by this cataclysm, and by which M. Belgrand considers that all traces of any previous river courses must have been obliterated, the Seine and its tributaries began to flow at an elevation estimated by him at from 80 to 100 ft. above the present level. This he proves, as we have already done, by the occurrence of the remains of land mammalia and of river and land shells in beds of drift at that elevation above the Seine on some of the hills near Paris. This part of M. Belgrand's work is admirably illustrated, both by general and local sections, and contains valuable lists of the mammalian remains, in the determination of which he had the advantage of the high authority of the late M. Ed. Lartet. Here again we cannot, however, agree with him in his *modus operandi*. The great boulders of sandstone, meulière, granite, etc., found in the valley gravel of the Seine, are attributed by M. Belgrand in the first place to removal to the line of the Seine valley by diluvial action, and subsequently to their drifting along the valley channel by the river action during floods of the Quarternary period, and he gives some remarkable instances of the power of water to remove large blocks, and of the rate at which such blocks move. When, however, it is considered that the granitic rocks of the Morvan have been transported some 150 miles, and other rock boulders in proportion; that the angles of many of the large blocks of sandstone and of meulière constantly show little wear, and that they are dispersed irregularly and at various levels, some imbedded in soft clays, and others in sand or fine gravel, and that these latter are often twisted and contorted, we can only explain the phenomena by the action of river ice and transport thereby.

M. Belgrand, on the other hand, shows that a prolonged and steady fall of rain, even if not very heavy, during the winter, now produces great floods—that such rivers as the Yonne and Cure flowing over impermeable strata are subject to sudden and great freshets after a heavy but short fall, whereas the Marne and Seine flowing over permeable strata have their floods retarded, but, at the same time, rendered more permanent by the rainfall having to pass through the strata and delivered in springs. He also shows that when the permeable strata become saturated by long-continued rains, they act as impermeable strata, and that the floods follow close on the rainfall besides being long maintained, so that in the remarkable and long wet winter seasons of 1658 and 1802 the Seine rose at Paris in the one case 29 ft., and in the other 24½ above its ordinary low level, and the floods in the last case lasted three months. M. Belgrand considers that this state of things was a normal condition during the Quaternary period, and he sees reason to believe that the rainfall at that period must have been very much greater than at present.

The ordinary low-water discharge of the Seine at Paris is 75 cubic metres per second; but during these great floods it rose to 2,400 and 2,000 cubic metres. M. Belgrand gives a list of eight such floods in the last two centuries, during which the discharge was above thirty times greater than the ordinary low-water discharge. In rivers flowing over more impermeable strata the difference is still greater; and he mentions that in the Loire at Orleans it has amounted to as much as 400 times, or 25 : 10,000. We may take the width of the Seine valley during the high-level gravel period at six kilometres, and during the low-level gravel period at about two kilometres; and M. Belgrand estimates that the river in flood had in the first instance a sectional area of 60,000 sq. metres, and in the second of 40,000 metres; and, calculating the flow at a given rate per sec., the discharge, as compared with that of the present, would be as under:

Discharge per second of the Seine at Paris in the present period and during floods in past periods:

		Extreme rise of river. Metres.	Discharge of river. Cubic Metres.
Present river	low water	8.81	75
	flood water	....	2,400
Old river during the Quaternary period	low level stage	20	27,000 to 60,000
	high level stage	13	

Large as these Quaternary period quantities are, M. Belgrand thinks that there are cases of recent occurrence to prove that it is possible to realize them. He mentions a flood following on a heavy

rainfall in the valley of the Armançon, a small river flowing over impermeable strata, with a basin of only 1,490, sq. kilometres, which had its discharge raised for a short time to 800 cubic metres per second; and he infers that under like conditions of rain and impermeability the Seine, with its basin of 78,600 sq. kilometres, might have its discharge raised to 42,444 cubic metres, showing, that notwithstanding the size of the old river channels, the area drained during a period of greater rainfall would have sufficed for the necessary water supply.

In confirmation of this larger and more permanent supply of water, M. Belgrand instances the presence of the Hippopotamus, the remains of which are found at several places in the Seine basin as well as in that of the Somme, and which would have required for its existence larger and fuller rivers. He also derives a further argument in the presence of this animal, against a prolonged and severe winter cold, which he considers would have been fatal to it. M. Belgrand, nevertheless, argues that the presence of the Reindeer indicates the six summer months temperature of Scandinavia, not exceeding in the mean 8 deg. Centigrade; but with such a summer temperature we hardly see how he can avoid the three months' winter temperature of the same latitude or of 4.6 per cent. A still more extreme winter temperature is in fact indicated by the presence of the Musk Ox and the Marmot. It is to be observed also that that the Reindeer at that time lived as far south as the Pyrenees, and that the physical condition of the drift deposits are, as we have before shown, strictly in accordance with a very low winter temperature. As the Hippopotamus is an extinct species, we do not know how far it may, like the extinct Elephants and Rhinoceroses, have been adapted to live in a severe climate. M. Belgrand's work is full of interesting details of the distribution of these and the other Quaternary animals, not only over the Seine basin, but in some cases over the whole of France. He gives also a monograph with figures, by M. Bourguingnat, of all the mollusca of this age found in the Seine basin. This well-known conchologist makes out that out of a total of 76 there are 38 new species which he considers as extinct, a conclusion which we expect English conchologists will hardly be prepared to agree with, as they have detected no extinct species in these deposits, and find only a few which are not local—a view in which we also believe most French conchologists join. The author considers that the same mammalian fauna is common to both the high-level and the low-level gravels. In one main point, however, do these gravels differ. In those of the high-levels of Montreuil and Bicêtre no human remains, no flint implements, have been found, whereas, in those of the low-levels of Clichy, Grenelle, etc., above 5,000 flints, more or less worked, are stated to have been found by a single collector. Besides these works of early man, M. Belgrand states that human bones, skulls, and entire skeletons, have been found in these lower gravels; but it seems to us that much of this evidence requires confirmation.

The Quaternary period of the Seine basin is coeval, in M. Belgrand's opinion, with the Glacial period, and he considers that it was brought suddenly to a close with the low-level gravels. To this Quaternary period the peat deposits immediately succeed, owing, as the author ingeniously suggests, to the suddenly diminished rainfall leaving the rivers clearer and under conditions favorable for the growth of peat, which he shows never takes place in river valleys subject to frequent and heavy floods, but always in valleys where springs abound, and the floods are few and not turbulent.

The latter part of the work is occupied with a minute account of the formation of gravel beds, and of the position of the organic remains, showing how all the features of those deposits are to be accounted for by ordinary river action, and that the mammalian remains are abundant precisely at those very places where a river with strong currents and numerous eddies would leave them. He endeavors to account also for the fact of all the bones of the larger animals being found in the coarser bottom beds of gravel, by the circumstances that these coarser beds were formed in those deeper water-channels along which only the larger carcases could have floated, and which were afterwards surmounted by those upper beds of sand and finer gravel, which he considers to be due to silting up (*alluvionnement*) of the channel where the river had

changed its course to another channel. The brick earth or Loess is ascribed by him, as by English geologists, to river floods. But instead of considering it, as we do, to be produced by successive floods at all the various levels of the river, from the high to the low level, M. Belgrand admits but two levels, the high and the low, and that owing to a sudden elevation of the land, the excavation between these two levels was produced at once without intermediate stages. Consequently, he considers that the height of the Loess above these two levels, marks in each case the rise of the flood waters. This, we think, is a weak point in his argument. According to his view, which he illustrates by a section, showing the range of the Loess up the hill slopes, he concludes that the floods of the low-level stage of the river rose, notwithstanding the width of the valley, to a height of 66 ft., and during the high-level stage, to a height of 43 ft., which give very much larger sectional areas for the river in flood than is otherwise necessary, and such as we conceived the area drained would have been insufficient to fill even with greatly larger rainfall. For, although the discharge of the Armançon may in a particular case of heavy rainfall have been so large as when multiplied by the whole area to give two-thirds of the required supply, still it is perfectly well known that the discharge by the main river never equals the sum of all its tributaries, and the discharge of the Seine at Paris on that occasion actually only rose to 1,250 cubic metres per sec. There are besides, beds of gravel on the slopes of Clichy towards Paris, and again on the slopes leading to Charenton, distinct beds of gravel at intermediate levels, though of limited extent.

Thus, M. Belgrand ascribes the gravel beds and the Loess of the Seine Basin to old river action, referring the red loam alone of the higher plains above to diluvial causes, in opposition to the view usually received in France, according to which all these Drift beds are divided into the three diluvial deposits of *Diluvium gris*, *Diluvium rouge*, and *Limon* or *Loess*. As we have already expressed very similar views respecting the commonly accepted classification, we cordially agree with the author on this point.

The illustrations forming the second volume constitute a very interesting exhibition of the art of Photo-lithography. The execution varies a good deal, and there are plates which, though valuable for their truthfulness, are rather indistinct. Some of the representations of the Flint Implements are excellent. The work is somewhat large and costly; but as a copious record of facts, an ingenious statement of theory, and a reliable representation of specimens, this work of M. Belgrand will be greatly valued by all those who feel an interest in the remarkable phenomena connected with the present configuration of the country, the distribution of life during the Quaternary period, and especially with the evidence bearing on the Antiquity of Man.

FIELD ARTILLERY.

From "The Engineer."

On the afternoon of Thursday, February 29th, Captain Sladen, R. A., of the Royal Laboratory, read a paper in the theatre of the R. A. Institution on "Flat Trajectories." Captain Sladen is the officer who proposed the 16-pounder gun of 3.3 in. calibre tried in competition with the 3.6 in. 16-pounder. The latter had been previously experimented on, and, eventually recommended by the special committee on muzzle-loading rifled guns of large calibre for field service.

The lecture was well attended. The lecturer commenced by enumerating the advantages of a flat trajectory, viz., accuracy, hard hitting, and covering the ground closely. He illustrated the last mentioned by a comparison of the falling angles of the Martini-Henry and Snider rifle bullets, the former of which in the last 6 ft. of descent travels over 104 yards, the latter only 62 yards of ground, so that these two distances represent the relative defended spaces, or spaces of danger to the enemy's infantry.

The lecturer next remarked on the imperfect investigations frequently made of the form of the trajectory of an ar-

tillery projectile. In the case of a small arm rifle bullet the arm is now generally fired with the elevation required for 500 yards, and targets are interposed at every 100 yards interval through which the bullet passes. This method is simple and direct, and the results obtained are matters of fact. With guns, on the other hand, the range due to some fixed number of degrees of elevation is often assumed to be the absolute measure of the flatness of the trajectory. This method of dealing with the question the lecturer considered wholly insufficient, and one which might lead to very erroneous conclusions, especially because the element of time is altogether omitted. The lecturer considered that the clearest way of looking at the matter is to compound the motion of the projectile into the horizontal and vertical directions, when it would be seen that the component which is due to the action of gravity is a simple fraction of the time; in fact the height of the trajectory is four times the square of the time of flight.

This, he remarked, is true in all cases. A ball thrown vertically upwards, and falling to the ground in a second, represents the vertical component of the path of every projectile with a time of flight of one second; for to all intents and purposes all fall at the same velocity. The trajectory, then, of two projectiles, with the same time of flight, will be more or less flat in proportion to the horizontal distance described. On this follows what may be given as the definition of the flatness of a trajectory, viz., "the ratio of its height to the range." Thus it happens that when the two 16-pounder guns tried in competition with each other are assumed to be placed on an equal footing when fired at the same degree of elevation, injustice is done to the 3.3 in. calibre, because, its initial velocity being less, it has for the same degree of elevation as its rival a smaller vertical component, and consequently it does not attain to the same height, and its time of flight is less. No one would argue that a train that travelled eleven miles had a slower rate than a train that travelled twelve, if the former had only eleven minutes for the performance of its work and the latter twelve. Of this nature is the injustice done to the gun with the lower initial velocity when it is assumed that equal angles of elevation give equal heights of trajectory, and ought to give equal ranges. Thus the 3.6 in. calibre has at 2 deg. 5 min. elevation a time of flight of 3.3 sec. against the 3 sec. of the 3.3 in. calibre. Far from having equal heights of trajectory, then, the former gun has one of 43.6 ft. and the latter of only 36 ft., consequently this should form an element in the comparison of the flatness of their trajectories. True conclusions cannot be bassed on the measurement of the ranges due to fixed angles of elevation without reference to their times of flight.

The actual angle of departure, however, is affected by other considerations besides the angle of elevation. Thus, where recoil is entirely checked, there is a tendency to rotation round the trail, and an increase of elevation follows. Hence it might be seen how unfair was the comparison made in one case between the 3.6 in. gun, with the recoil checked, and the 3.3 in. gun when recoiling freely. Again, on the other hand, where recoil is not checked an increased velocity of recoil increases the actual angle of departure. This the lecture illustrated by a diagram, in which the line of departure was drawn, not to the muzzle at the moment of ignition of the powder, but to the muzzle when it has mowed back slightly, as is actually the case when the shell leaves it. This diagram was, in fact, similar to that commonly made in astronomical works to show the effect of aberration of light. For these causes, then, the lecturer considered that the sound method of comparison of the flatness of trajectories would be that of the comparison of the ranges due to equal times of flight.

In passing again to the question of the relative powers of the 16-pounder guns of larger and smaller calibre, the lecturer remarked that the shell of smaller calibre, although, no doubt, starting with a lower velocity and slightly less flat trajectory, had, owing to the decreased surface it opposed to the resistance of the air, actually caught up and beaten its rival at so short a range as 724 yards. This he considered was before it arrived at what might be called an ordinary artillery range. At 1,000 yards it had a superior velocity of 11 ft. per second, at 2,000 of 25 ft. per second, and at 3,000 of 34 ft. per second. Thus at all

artillery ranges it hit harder and had a flatter trajectory. Shrapnel would thus be superior in its effect, and the same would be true of its common shell. Yet since this gun had been constructed on the "lines" calculated for its rival, better results still might be looked for if made on lines specially designed for it. The only advantage, the lecturer considered, that could be possibly claimed for the 3.6 in. gun was a slight increase in the interior capacity of its shell. Although it had burnt its charge of 1 lb. 12 oz. of "R. large-grained powder" more completely, it remained to be seen whether the result would be the same if ordinary large-grained "L. G." powder had been employed. Where reduced charges were resorted to, the advantage would be still more in favor of the smaller calibre, which admitted of the vent being placed further forward in the bore.

The lecturer then suggested the trial of a lighter gun with a smaller firing charge, observing that the Prussian heavy field gun was only about the same weight behind team as the English horse artillery, and might be compared with it more justly than with a gun weighing 4½ cwt. heavier. There had been a recent report of an experiment as to the powers of mobility of our own horse artillery in India—made by Major-General Tombs—having been followed by the immediate death of four horses. If true, this showed what a serious matter was the consideration of the weight behind team.

After some preliminary remarks made by the chairman, an animated discu sion took place, if the word discussion can be applied to the observations of a number of speakers all advocating the same principles. Thus one officer observed that the smaller shell, with even the same velocity as the larger, would penetrate deeper, owing to its reduced surface of resistance. Another remarked that the gun, being designed specially for reserve artillery, must be expected to be called upon to open fire in the teeth of batteries already in position. Power at long ranges, therefore, was a special recommendation.

The chairman in vain invited officers who were advocates of the larger calibre to speak in its favor. It appeared that no artillery officer could be found ready to advocate that side of the question, and the proceedings were concluded by a complimentary expression of thanks to the lecturer for his paper.

THE PUBLIC WORKS OF PARIS.

From "Engineering."

Among the work included in the duties of the Department above the level of the public thoroughfares, we have spoken of the promenades. Lighting follows next. In 1855 the city of Paris conceded the privilege of gas lighting to a company formed with a capital of £2,200,000, under the title of the Parisian Gas Lighting and Heating Company. In compensation for the monopoly accorded to this company, and which consisted in the exclusive right of establishing and mantaining gas mains beneath the streets and roads, it was undertaken:

1. To reduce the price of gas to 6s. 9½d. per 1,000 cubic ft. for private consumers, and to 3s. 4½d. for public use.

2. To pay an annual tax of £8,000 as rent for the ground occupied by the mains, and a duty of 5.06 pence per 1,000 ft. for all gas burned in the city.

3. To extend the service wherever the administration deemed necessary.

4. And, lastly, to divide all profits with the city when the receipts exceeded 10 per cent. on the capital; to terminate on the 1st January, 1872.

In 1860 the obligations of the company were extended, and in obliging them to lay down 113 miles more mains, they were authorized to increase their capital to £3,360,000, and it was stipulated that the division of profits above 10 per cent. should be made on the total, instead of on the first capital.

In 1870 the city, having serious difficulties with the gas company on the subject of the duty of 5.06 pence per 1,000, wished to improve the lighting of the districts served by the 113 miles of mains above alluded to, and which were but imperfectly lighted, and desiring to enjoy larger benefits from the division of profits, made a new treaty with the company, regulating the duty, and stipulating for a division of the profits since 1869 on

all net income beyond £496,000 up to 1887, and from that date beyond £450,000 to the end of the concession.

Recent events have served to reduce the profits due to the city, and it is proposed amongst the new taxes to levy one that will absorb them altogether, so that the existing agreement will have to be modified again. The public lighting in Paris comprises 31,122 gas jets, 596 petroleum oil lights, and 971 colza oil burners. This expense for 1870 amounted to £176,000 This outlay will have—at least temporarily—to be reduced, by diminishing the actual amount of lighting given to the city.

The substitution of jets with large openings for those with narrow ones has alone sufficed to effect a radical reform. The burners have openings equal .023 in., and consumes 4.9 ft. per hour. These give 3 times the light of the old burners with the same amount of gas. The illuminating power is checked each night in 11 test rooms distributed over the different quarters of Paris.

The service of concessions of the thoroughfares has for its chief duty the levying of taxes on the chairs and tables placed in the streets outside cafés, the collection of rents of the small open-air shops, the establishment of kiosks, the maintenance of public urinals and water-closets, and the inspection of public advertisements. The Department of Public Vehicles regulates the service of the cabs and omnibuses.

An agreement made in 1862 conferred on the Compagnie des Petites Voitures for a space of 50 years the exclusive right to establish in the streets vehicles for the conveyance of passengers either by the hour or the course. The following obligations were imposed:

1. To establish at once a stock of 3,500 vehicles, and to increase the same at the rate of 100 vehicles a year.

2. To pay a tax of 1 franc per day per vehicle.

3. To divide with the city all profits above 8 per cent.

4. To maintain efficiently the whole of the material, plant, etc.

5. To divide with the city, at the termination of the concession, the available surplus. This company not having been able to prosper under these conditions, the Government made a decree in 1866, on the occasion of a general strike of the drivers, proclaiming a free trade in public vehicles. Every one was thenceforth at liberty to put in circulation a carriage for public hire, upon the sole condition of paying a tax of 1 franc per day. The company was indemnified for the loss of its privileges by an annual compensation, payable during 47 years.

But the regime of liberty has not profited up to the present; neither the public, the private speculators, nor the old company, which continues without monopoly the exercise of its industry. An important improvement in the service is expected by the employment of distant counters, on the application of which an inquiry is now being made.

The omnibuses are regulated by a treaty of 1861, conceding for 56 years to a company the exclusive right of circulating on the streets, and stationing on the public way, omnibuses serving for the general transport of passengers. The Government privilege to authorize all other schemes for transport on the public streets, or the establishment of tramways, in reserved.

In exchange for these advantages the company engages to pay to the city for the right of standing on and using the thoroughfares, a sum of £80 per year per vehicle, and the city shares, besides all profits over 8 per cent. on a capital of £1,200,000. The company is also bound to establish new lines and to increase the number of vehicles on existing routes whenever the administration shall require.

Under this treaty the omnibus service has been greatly improved. But the company, which prospered up till 1869, has not paid dividends since, and has applied for authority to increase, by 5 centimes, the rates of fares fixed at 15 centimes.

The tax on vehicles of all classes brought to the city a revenue of £133,600. The extension of tramways into Paris is being seriously discussed at the present time. Of late years foreign capital has flowed to Paris, and financial societies press forward to execute municipal works. The time appears to have come to study carefully the wants of the city, with a view to establish iron roads as much in the suburbs as in the routes radiating towards the principal localities

in the Department and to examine into the question of tramways. Upon the latter the experience gained is most favorable as regards the comfort and convenience of passengers. But horse railroads appear out of the question equally in the narrow streets and on the great thoroughfares of Paris, already crowded to excess. Meantime it is necessary to confine experiments to certain roads presenting special and favorable conditions, and to wait till experience can decide on the advantages and disadvantages of tramways with regard to their influence on the road itself, and their effect on the traffic, and the public should, besides, become used to the new means of transport outside Paris before it is introduced to the interior of the city.

The question of low level roads presents great difficulties They could be only constructed at great cost, and would, instead of desiring to reduce the traffic by relieving the streets of the heavy goods vehicles, only be frequented by passengers in scanty numbers. At the utmost, if such means of circulation were tried, they would only be permissible beneath the most crowded streets. High level roads, which have also been proposed, would be very difficult to establish, and, besides, the purpose they would serve would be extremely limited.

The last division of the service of Public Works in Paris is that of architecture and the fine arts. It includes the maintenance of public buildings, new architectural works, and fine art and historical monuments.

The report of the Chief Engineer of the Department shows what enormous sums have been spent to make Paris what it is, what large amounts must be yearly devoted to the maintenance of the various services, and how difficult it is to reduce these expenses despite the present necessity for so doing. Indeed, the utmost proposed reductions make after all but a small difference in the outlay of the staff.

When by degrees an administration has been led to occupy itself with a thousand objects which were unknown a few years ago, when the beauty and luxury of the city of Paris have grown to a necessity not only for France, but for the world, it is almost impossible to reduce the scale of magnificence which has become familiar. But there are doubtless many small reductions and economies to be effected, and it is to be hoped that the Municipal Council will not fail to effect all possible reform in this direction, while they carefully abstain from touching any of the great attractions and charms of the city.

THE TEMPLE OF DIANA AT EPHESUS.*

From "The Building News."

Most people have heard of those famous Seven Sleepers of Ephesus, who, taking refuge from the persecutions of Diocletian at the close of the third century, fell asleep there, and woke up two centuries afterwards to find a new world and a Christian empire. Scarcely less romantic have been the fortunes of the famous Temple of Diana of Ephesus, one of the seven wonders of the ancient world. Destroyed by an earthquake, and plundered by the Goths in the 3d century of the Christian era, it served as a quarry for the architects of the Byzantine city built at Ephesus, probably in the time of Justinian, till, the appetite for plunder being exhausted, the remnant of its ruins was allowed to silt up silently under the slow but sure action of alluvial deposit. Thus the very site of the world-famous temple was obliterated till British enterprise, piercing through 22 ft. of alluvial deposit, came suddenly on the marble pavement, still strewed with broken columns, capitals, and fragments of sculpture. This discovery, one of the happiest efforts of archæology in our time, is due to the persevering energy and sagacity of Mr. Wood, who, having searched for the site of the temple since 1863, first at his own expense, and subsequently with funds supplied by the trustees of the British Museum, has been rewarded, after long years of toil, by the discovery of the site, which was finally ascertained about this time last year. During the last twelvemonth a large area of the temple has been

*Extract from a letter to the London Times.

cleared to the pavement, and various architectural marbles have been found, more or less mutilated, lying as they had been left by the barbarous despoilers in Byzantine times. The diameter of these columns of the temple being 6 ft., the scale of the architecture is, of course, colossal—exceeding, it is believed, in proportions the celebrated Temple of Jupiter Olympius at Athens, the temple at Branchidæ, and all other extant examples of Greek architecture.

The great weight of the marbles discovered rendered it necessary for Mr. Wood to apply for naval aid, which was supplied by the British Government with that alacrity which has distinguished the Admiralty in the history of our recent archæological expeditions, and which can alone insure the complete success of such arduous enterprises. Her Majesty's ship Caledonia, a grand old iron-clad three-decker, was at once sent to Mr. Wood's assistance, and has been engaged since the beginning of this month at Ephesus and Smyrna in hauling, packing, and shipping the marbles of the temple selected by Mr. Wood for the British Museum. I have been favored with a sight of these huge masses before they were packed. The largest, weighing upwards of 11 tons, is part of a drum of one of the *cælatæ columnæ* mentioned by Pliny—*i.e.*, columns with figures sculptured on them, of which the temple had thirty-six. Of this bold, striking innovation in Greek architecture there exists, it is believed, no other example except at Ephesus. The relief on this drum appears to represent an assemblage of deities, of whom the only one who can be positively identified is Mercury, the rest being draped female figures. On a stone from a pilaster, corresponding in dimensions to the sculptured drum, is a relief representing Hercules struggling with a draped female figure, and on another fragment of a drum are the lower halves of some seated and standing female figures. This sculpture is very bold and effective as decoration, but wants the ineffable charm and freshness of the frieze of the Parthenon, while in masterly vigor of execution and dramatic force it falls far short of the frieze of the Mausoleum. It is careless and inexact in execution, and has the characteristics which we might expect to find in the Greek sculpture of the Macedonian period, when work was executed rapidly to gratify the vanity of kings, and when an Oriental love of mere mass rather than beauty of design had begun to affect both sculpture and architecture. Allowing for this first disappointment, I own that I gazed with peculiar interest on these relics of those famous columns on which St. Paul must have gazed when he preached against them, but which local fanaticism, aided by local vested interests, preserved in all their splendor for three centuries after his coming.

The architecture of the Temple of Diana is Ionic. Mr. Wood has very properly selected such fragments as will show what the base, the capital, and the order generally were like. Once housed in the British Museum, they will furnish materials out of which, not, perhaps, a complete restoration of the temple, but a new chapter in the history of Greek architecture can be constructed, just as out of the fossil bones of the Megatherium an Owen reconstructs lost types in the animal kingdom.

The stones were very heavy, the mud of Ephesus tenacious, and the weather variable; but the Caledonia's blue-jackets have done their work with an alacrity and good humor characteristic of blue-jackets in these expeditions, and by the end of the week the ship will leave this port with her precious cargo, bound for Malta.

NEW PRUSSIAN RIFLE.

From "The Mechanics' Magazine."

It is stated upon good authority that the German Imperial military authorities have recently come to the conclusion that it is necessary to remodel the service-weapon. The new rifle will neither be a needle gun nor a chassepot, but a compound rifle, combining the best features in detail of all the rifles known and experimented on in recent years. It is admitted that the last war demonstrated the existence of grave defects in the needle gun, notably in its relatively short range, due

to the curve of its trajectory, the disproportion between the weights of the projectile and the powder charge, or other causes. It is not proposed to adopt either the Werder or the Vetterlini rifle in lieu of the needle gun; in fact, the model of the new gun is not yet complete. But, the problem being to provide a breech-loading arm, of small calibre, easily manageable, and of long range, it is proposed to shorten the barrel, alter the rifling, and diminish the bore.

The consideration of the new cartridge has reached a more advanced stage. It is decided to discard the paper envelope, and adopt the metallic case of brass foil, and also to vary the relations between the bullet and the charge in point of weight. All these modifications will, it is anticipated, have material effects upon the trajectory, the range, and the durability of the new weapon. It is expected that the new arm will be ready for approval at the beginning of the new year, so that a sufficient number may be supplied for experiment in the course of firing during the ensuing summer; and thereafter several corps will be exercised annually in the use of the new weapon, so that in about four years the whole army will have become familiar therewith, previous to which, for obvious reasons, the new armament will not be generally adopted.

It is announced to be the intention of the authorities at the War Department to have the whole of the old pattern smooth bore 68-pounder guns, now in store at Chatham, converted into rifled guns, a considerable sum being taken for the proposed work in the estimates for the approaching year.

ON TRINKETS AND THEIR MANUFACTURE.

By W. G. LARKINS, Esq.,

From "Journal of the Society of Arts."

The desire for the adornment of the person is one of those curious bonds that unite humanity. It is equally strong at both ends of the human race—the dusky belle of a savage African tribe, who pierces the cartilage of her nose to hang therefrom an uncouth ring of gold, is actuated by, to say the least, no lower motive than that which induces some beauty, nurtured under that civilization upon which we pride ourselves, to pierce the cartilage of her delicate ear, to hang therefrom a pendant of jewels; and the dandy of some Indian village, upon whose brown breast is tattoed the head of the lion, the fierce courage of which he desires to emulate, is about on a level with the swell of our own day of horsey proclivities, who sticks into his scarf an imitation of the head of that animal he would have us think he knows so much about. Vanity and superstition are the two great motives that induce the wearing of ornaments—a harmless vanity—perhaps a superstition that may be pardoned—but vanity and superstition, nevertheless. Out of this universal desire has grown up, as a compensation perhaps, an immense industry, or, I should say, a series of industries, by which thousands are enabled to earn their daily bread; and one can safely say this, that at no other time have articles of trinketry been so easily attainable as at the present time. If a person goes undecorated, it is his or her own fault, for lockets, and very well made ones, too, may be had for one penny. One, in the shape of a book, with a likeness of the Prince and Princess of Wales included, had a great sale a little while ago, its wholesale price being one halfpenny; and some brooches made in Germany are now being sold wholesale at the astounding price of three shillings a gross—a farthing each.

If the universality of the desire for personal ornament is a fact, no less a fact is its antiquity. The earliest records of mankind refer to the trinkets worn at the time; indeed, I am perfectly prepared to believe that, if there ever was a pre-historic man, woman, or child, he, she, or it wore some kind of decoration of the period, considered to enhance the personal attractions of the wearer. It is also worthy of remark that the early forms of personal ornament are retained to this day, and, more than that, they are still the popular forms. The workmanship is better, the skill of the chaser and the engraver enriches them, but the circle, the

oval, and the crescent, with the simple knot or tie, are the basis on which the larger portion of manufactured trinketry is formed.

Rings are, perhaps, the oldest form of trinkets,—rings for the fingers, legs, and arms. A ring is used as the outward symbol of the married state, as symbolizing eternity. At a very early period rings were used as a medium of exchange, and are still, I believe, in Western Europe and the East, and as the money of African trades, for whom they are specially made of a mixture of copper and iron, and known as "manillas."

Though I by no means think that the slavish imitation of past productions is a thing to be encouraged, or that it is impossible in the present to produce any article that shall not be as original, as graceful, and artistic as anything that has been produced before, yet I do think that designers would do well to study some of the examples of past times that have been preserved to us. There are numbers of beautiful forms, in the British Museum and elsewhere, that are well worth attention and reproduction.

Mr. J. S. Wright, in his paper on "The Jewellery and Gilt Toy Trades," read before the British Association, says:—

"The chief seat of trade formerly was Derby, where large quantities of common and medium jewellery were produced, Edinburgh and London manufacturing the finest goods. The trade has almost disappeared from the former places, and London now depends mainly upon Birmingham for the supply of articles suitable for the middle classes. Since 1836, the trade may be said to have been in a flourishing condition, but during the last twenty years its progress has been almost marvellous. The discovery of gold in Australia and California, the vastly increased wealth of England and her colonies, together with the desire for personal adornment, have united to give an unparalleled prosperity to this branch of industry, which now, directly and indirectly, affords employment to a larger number of persons than any other trade in Birmingham, whilst its increasing demand for novelties undoubtedly tends to develop in a larger degree the inventive and artistic faculties of a considerable portion of the inhabitants. With the exception of a few machinists (and in very busy seasons the workmen in the gun trade), the jewellers are the best paid of the Birmingham artisans. The rate, of course, varies considerably, but he is a poor workman who can only earn 25s. weekly; 30s. to 50s. may be considered the average of wages. Some obtain much more. Enamellers frequently gain as much as from £3 to £5 weekly. Boys are usually apprenticed at fourteen, when they earn 4s. per week, which is increased annually until they are twenty-one, when they generally receive 10s. or 11s. working, as a rule, from eight to seven, with intervals of an hour and a quarter for dinner, and half an hour for tea. Youths sometimes make a considerable sum by working overtime. It is somewhat singular, and contrary to what might have been expected, that only comparatively few females are employed in this trade; its cleanliness, and the delicate manipulation required, would appear to adapt it especially for women. Two branches only give them employment—one is the "guard-chain," and the other is the ordinary press work, when they cut out or form the "roughs;" but a considerable number indirectly obtain their living in connection with the trade by making paper and leather boxes, which are largely used, not only to protect, but also to set-off the finished article.

"The jewellery trade furnishes a most interesting and important illustration of a peculiarity which places Birmingham in favorable contrast with every other large town and centre of industry in the kingdom—namely, the large number of small but independent manufacturers it supports. There are comparatively few large manufactories, most of the articles for which it is noted being produced in shops where five to fifty hands are employed. Probably nine out of every ten of the master jewellers, who are now carrying on business on their own account, were originally workmen. In one instance, at least, not less than twelve independent concerns are now in active operation, each employing a number of hands, the principals of these twelve concerns having all been employed as apprentices or workmen in a manufactory which itself has been established within twenty-five years.

"All that is needed for a workman to start as a master is a peculiarly-shaped bench and a leather-apron, one or two

pounds' worth of tools (including a blowpipe), and for material a few sovereigns, and some ounces of copper and zinc. His shop may be the top room of his house, or a small building over the washhouse at a rent of 2s. or 2s. 6d. per week, and the indispensable gas jet, which the gas company will supply on credit. With these appliances and a skilful hand, he may produce scarf-pins, studs, links, rings, lockets, etc., for all of which he will find a ready market on the Saturday, among the numerous "factors," whose special business it is to supply the shopkeepers throughout the country.

"The causes thus indicated, which have so largely contributed to the establishment and prosperity of the jewellery trade in Birmingham, would, however, be insufficient of themselves to give it a permanent character. No doubt, success for a time largely contributes to the permanence of a trade; dealers in the various tools, stones, and materials required are drawn together, and this affords great facility to manufacturers, especially to those of small capital. Then the demand for novelty stimulates the ingenuity of the producer, and, by insuring a continued supply of new styles, developes trade. There is no doubt it is the superiority of the workmanship that has continued the trade in its prosperous condition; and it is upon this superiority that reliance may be placed for its further development and permanent establishment in this locality."

FRANCE.

It is generally supposed that the greater quantity of mock jewellery comes from France. This is not the case at the present time. It used to be so, but for the last few years the manufacture has been steadily declining, and I think I may say that, whereas a thousand pounds' worth used to go to Paris for every hundred pounds sent to Birmingham, that now the reverse is the case, and Birmingham takes the thousands, whilst France takes the hundreds. The cause of this is easily divined. The manufacturers of France, with their undoubted artistic skill, cannot compete with our mechanical appliances. The superior machinery that has been erected at Birmingham has brought the trade to us, and it ought to be a matter of congratulation that the progress of our own industry and manufacture is thus meeting with reward. The late unhappy war probably gave the final death-stroke to a manufacture that once was of great proportions. There is also another reason why France cannot compete with Birmingham, and that is this: A manufacturer, having ordered a die, and desiring to try the market with a few samples, has to pay dearly to the die-sinker for them, and is, therefore, unable to put them forward as cheaply as he might, were he able to stamp himself. Of course, if he is able to give an order for some large number, he can do the thing cheaply; but should he run short of a particular pattern, he is unable to supply a small order. In this country, a manufacturer, having his own dies and presses, can do as he pleases, can at once arrive at an approximation of the price it will pay him to sell at. I am afraid that France having once lost the trade, will never recover it. English manufacturers head the cards they affix their articles to with inscriptions in French, and even put French names to them, because of the reputation French jewellery once had; but the largest portion of that so labelled is nearly all made either in London or Birmingham. This reputation it is found convenient to keep up, mostly because French artistic skill is so much higher than British; and although, at the present time, we are beating the French in the manufacture of both real and imitation jewellery, I do not think that in artistic skill we are any way near them. They certainly do turn out some beautiful designs, the result of the better acquaintance of their artist-workmen with works of art and design, and the result of the artistic education they receive. It seems to me, looking at the French trinketry, that they excel more particularly in combinations. It is, perhaps, one of the most difficult things possible to put in harmonious contact a variety of materials, of different colors, in many different ways, so that there shall not be a wearisome sameness. The British workman has, however, been so educated, that when once his mind is set upon producing anything in a certain manner, and his fingers get accustomed to work in a certain way, it is very difficult to get him to alter his manner, and manufacturers find it better worth their while to turn out thousands of an article all of one shape and pattern than to give their workmen a little license to vary

and alter. Machinery has, of course, done much to increase this; and if it has cheapened production, it has, to a certain extent, fettered design.

One of the particular branches of manufacture that the French excel in, and we cannot touch, is that of the application of steel. This manufacture originated, I believe, in England, but was adopted by the French, who now supply us with the ornaments, the trade having dropped in England altogether. The steel ornaments are made up of small nails or pins of iron, the heads of which are first of all hardened as steel, then faceted and polished. They are then riveted to the ornament, which is fashioned previously.

GERMANY.

Germany manufactures a considerable quantity of jewellery. The principal exports to this country are very cheap imitations, in the form of ear-rings and brooches, etc. Among the specialties of the German manufacture are the articles made of the garnets of Bohemia. The Bohemian garnets are not of the finest, being somewhat black; still they make an effective ornament. The grinding and polishing of them gives employment to a large number of persons during the summer. When water is frozen in the winter, they are unable to continue the operations; therefore, there are times when it is difficult to obtain this jewellery. The garnets are mounted by the working jewellers of Prague.

Silver filagree is another *specialité* of German export jewellery. Such a bracelet as the one on the table, which displays a large amount of work, it would be almost impossible to produce in England for the same price on account of the dearness of labor. There is some taste in the design. Glass beads, and little glass brooches with a bit of tinsel upon them, find a ready sale in the English market, roughly and coarsely as they are made. The agate ear-rings and brooches sold wholesale at about 7½d. per pair, are ground and polished like the garnets; their chief fault, however, is the mounting. The German workmen have not quite the capabilities of turning out things cheaply and strongly. The characteristics of all German jewellery is that it is, as far as the metal work is concerned, thin and frail.

Vulcanite, to which I shall refer presently, comes principally from Germany. In some things, glass-working, for instance, Germany can excel. Glass beads she makes in large quantities, as well as imitation pearls. The glass ear-rings on the table are sold wholesale in this country at 8d. per dozen pairs. The rococo work, of which there was a large quantity exhibited in last year's exhibition, is another species of ornament.

Ivory carving is another industry which the Germans have turned to account in manufacturing personal ornaments, and they can produce brooches and other things at a very cheap rate.

Some years ago there was a considerable quantity of iron ornaments imported from Berlin, where the manufacture of it by casting forms a large industry. They were sold just as they came from the mould, and had a rapid sale here at the time, and were very effective and delicate in appearance. By great care in the choice of iron, and other precautions, the founders are enabled to obtain the metal in a degree of fluidity necessary to fill the minute and sometimes delicate moulds. The public taste has herein altered, and it is doubtful if any could now be obtained.

MATERIALS.

If the wearing of trinkets is a universal passion, the materials of which those trinkets can be made are almost endless in number, ranging from human hair through the animal, vegetable, and mineral world, down to the granite foundations upon which the world is built. Every metal has had its turn but one, for I have not heard that mercury, in its natural state, has yet been made into a brooch or ring. Various kinds of woods, ivory, bone, hair, pebbles, precious stones, glass, leather, paper, and the shells of mollusks, granite, and plaster, are among those in use at the present day; and what will or will not be turned to account, as the tastes of the public vary, or the ingenuity of manufacturers increase, I cannot say. There is no manufacture that affords a greater range of material, or of opportunities for the display of artistic talent in using it. And when we take into consideration the richness and value of some of the materials, we may say that it affords a grand opportunity for a combination of both value and design.

GOLD.

Gold, of course, is the metal from which the greatest portion of jewellery is made, and, besides its intrinsic value, no metal is so pleasing in appearance, or is so well suited for the purpose. Even when of low standard, it is able to hold its own against other metals; and this being the case, a successful imitation of gold is what the maker of mock jewellery most desires.

While talking of gold of low standard, I may perhaps be allowed to say, as affecting the public very much in this matter of trinkets, that many persons imagine that in buying a gold ring for instance, because it is hall-marked, it must be of good, or, I will say, fine gold—indeed, in some cases, that it is 18-carat gold, which every one knows is the best adapted for manufacturing purposes. But the fact is, a hall-marked trinket may be as low, I believe, as 9-carat gold, that is to say, the greater portion of it is not gold at all, but alloy. Trinkets made of 18, 16, or 14 carats possess a proportionate intrinsic value of their own. They permit of delicate workmanship, while they are hard enough to resist wear; but below that, although the trinket itself may have an artistic value, yet it can hardly be said to be of gold, 12-carat being half gold and half alloy, and 9-carat gold having but little more than a third of the precious metal in its composition. I need not say that 3, 4, and 6-carat gold is practically of but little value. Till the reign of George III., the standard was fixed at 22 carats, then at 18 carats; subsequently exceptions were made, and now only wedding rings are required to be of 22-carat, or what is called guinea gold. Silver, on the contrary, has a fixed standard, and all hall-marked silver is of the same metallic value. I cannot but say that the suggestion which has been made by Mr. Streeter and others, that the public should insist that the jeweller of whom they may buy should insert upon his invoice the value of the gold he sells, is a good one. This would check certain malpractices that undoubtedly do exist, and I am not at all sure but that it would lead to the fixing of one standard, as is the case in France and other countries, and that then the public would get their value for their money, and we should, by means of our superior powers of production, be enabled to increase our exports of jewellery to the Continent, where at present, it is looked upon with considerable disfavor, not on account of its design or manufacture, but because of the doubt which exists as to its precise value.

There is one reason why the fixed standard of gold is of less importance in this country than in others. England, unlike most continental countries, does not possess a distinctive type of jewellery. In France, Belgium, and other countries, there is a national peasant jewellery, which is handed down from generation to generation, and considerable sums of money are expended in the ornaments which are to become heirlooms, and the manufacture of them is an important industry. Now, as peasants, or persons who are unable to form correct estimates of the value of gold from its appearance and weight, would be greatly liable to be imposed upon, and their savings be exchanged for trash, unless some stringent rule were laid down, a mark of purity, which has only one meaning, is an important thing. Every one knows the mark, and to see it upon the article they may desire to purchase is a guarantee to them that they are justified in expending their money upon it. The amount of money thus locked up in France, Holland, Spain, and other countries is enormous. In England, on the contrary, among the great bulk of the people there is no family jewellery. The great houses of the country pride themselves upon their jewels, but a country farmer, who, it may be, cultivates the land his ancestors for hundreds of years back did, would laugh at the idea of family jewellery; his pride would lie in a different direction. This, doubtless, affects our English manufacture to a certain extent, for trinkets are bought to serve their purpose and their time; they are used to-day and thrown away to-morrow. They grow old-fashioned, are discarded, and, if of gold or silver, are sold as old metal. A French peasant woman would as soon think of selling her ear-rings as old metal, because they did not accord with Paris fashions, as she would think of selling herself for a slave. This want of reverence for personal ornaments may have made manufacturers much more careless, both in design and material, than they would otherwise have been.

SILVER.

Silver is used, to a certain extent, in the manufacture of ornaments, but the alloys

I shall presently refer to have beaten it out of the market. At one time, silver chains were very commonly worn, and many a schoolboy who received as a present a silver watch and chain, went back to school with a feeling of considerable pride in the possession of them. Now, it is extremely probable that, with regard to the chain, at all events, he would be very much better pleased with one of Mr. Pyke's Abyssinian Alberts. To see silver chains now is a rarity, except among rustics, and they are very seldom displayed for sale in the shop windows. I must call attention to the beautiful oxidized silver casket upon the table, lent by Mr. Streeter. It is of exquisite pattern and workmanship, and shows what can be done with that method of treating the metal. There is no doubt whatever that it affords an opportunity for treating silver in a unique and artistic manner, and trinkets are made of it, though I have none here to-night to show you. At present the public has not been sufficiently educated to appreciate them, but I believe that before long, as taste in these things improves, a very large industry will arise in connection with the manufacture of oxidized silver articles; the metal is sterling, and wears well; it is capable of elaborate workmanship, and the treatment of it by oxidation gives it a distinctive character above a mere silver ornament. The national brooches and pins, set with various stones and pebbles, and known as Scotch jewellery, is a local industry of some merit, and the style seems very suited to the somewhat barbaric forms of the Scotch national ornaments. The stones used are cairngorms, yellow amethysts, jasper, and agate.

ALUMINIUM AND ITS ALLOYS.

The discovery of the metal aluminium, and the success of the experiments of Deville, Gerhard, and others, by which its production in large quantities was proved possible, had a wonderful effect upon the manufacture of imitation jewellery, inasmuch as it gave the manufacturer a metal which was of as good a color, as workable, but not so expensive, as gold. With regard to the metal aluminium itself, I may refer you to a paper read in 1859 by our Secretary, Mr. Le Neve Foster. It is a very malleable and ductile material, about 4 times lighter than silver, and nearly as light as glass; and, from the properties it possesses, it is capable of being applied to a variety of uses. It has been made into jewellery and ornaments of various kinds, but has never, I think, become popular. Some very beautiful articles have been manufactured from it, and in some respects it has an advantage over silver; it is not affected by the atmosphere, while it works easily under the graver. It is, however, rare to see articles made from it exhibited, though, ten or twelve years ago, buttons, shirt-studs, and brooches might have been bought cheaply in the Lowther Arcade and other places. It is, however, largely used for the mounting of telescopes, opera-glasses, surveying instruments, and spectacle frames, its lightness being of value in such articles; and, though it is admirably suited for the wheels of clocks and watches, I do not find that it is extensively, if at all, used. Although its use as a pure metal for trinkets and ornaments has not been established, yet, as I said just now, it has had a very marked effect upon the manufacture of mock jewellery, from the fact that, with copper, it forms an alloy that in color approaches gold more nearly than any other. The aluminium, when used in small quantities, (the proportion being about 5 per cent. of aluminium and 95 of copper), gives a hardness to copper, rendering it capable of being polished to a high degree, but without destroying its malleability, such an alloy having also the further merit of not being sensibly tarnished by exposure to air. The value of such an alloy as this to the maker of imitation jewellery is at once seen. In order to show this, I have here some pieces of chains, one of which, Mr. Streeter tells me, is 18-carat gold; one, Mr. Pyke says, is of what he calls Abyssinian gold, it being really of such an alloy as that I have referred to; and one which is of a "composition," which, up to the discovery of aluminium, was the nearest approach in color to gold that could be got. The difference in favor of the aluminium bronze, which is its correct title, is evident. The "composition" to which I refer is probably an alloy of copper and zinc, in the proportions of 66 parts of one with 34 parts of the other. Pinchbeck is another alloy of copper and zinc, of which watches and other trinkets were made, but it tarnished rapidly, and was much too dark in color even for 18-carat gold,

while the mosaic gold, as the alloy I have mentioned is also called, approaches, when polished, very nearly to the appearance of 9-carat gold, of which a large number of trinkets are made and sold.

DOUBLE D'OR.

I have said that the materials of which trinkets can be made are innumerable. Among those that are in use at the present time, and have been used with success, I may mention *double d'or*, which is a manufacture of French invention, dating from the year 1830, and which is produced as follows:—A plate of copper has a layer of gold placed upon it, the thickness of the gold being as one to eleven of the copper. The two plates are made to adhere by solder, and are then passed through rollers till they have been reduced to the required thickness. Great care has to be exercised to keep the metals from parting. It is evident that an article made from such a plate must have a gold surface, more or less thick, and that it is less likely to suffer from abrasion or wear than gilding, where the deposit is oftentimes very infinitesimal, three pennyworth of gold having been known to cover a gross of livery buttons.

TORTOISE-SHELL AND ITS IMITATIONS.

Tortoise-shell ornaments are well known, and, inlaid or in combination with the precious metals, it forms beautiful trinkets. Some ornaments have been made from what is called artificial tortoise-shell, another French invention. This material was first introduced by M. Pinson, of Paris. It is obtained by melting, at a moderate temperature, gelatine with a small amount of metallic salts, and running the whole into moulds. The peculiar markings and grain of the tortoise-shell is obtained by staining the substance with hydro-sulphate of ammonia. The objects produced, such as bracelets, brooches, combs, and various other fancy articles, are then polished and made ready for sale. Some of them are inlaid with gilt metal or silver, and some very pleasing effects have been produced. An imitation tortoise-shell is also made from horn, which is softened by heat, pressed in a mould, and then re-hardened.

SHELL, ETC.

Most trinkets of what is called mother-of-pearl are cut from the shell of the oyster, much in the same way that pearl buttons are made. The shells are imported specially for the purpose, and the portions of them likely to be useful are removed by means of small saws revolving in a lathe. These portions are then split, and rendered equal in thickness by rasping. The various shapes are then cut out, and are finally polished by the use of rotten-stone.

In the Exhibition of 1862, Mr. Harry Emanuel exhibited some ornaments in ivory, which were quite new in style, and there is no doubt whatever that the material is capable of being treated in a most artistic manner. It is semi-transparent, and can be used either with its natural color, or stained and painted, still retaining its natural surface.

The same gentleman also exhibited what he called pink pearl-shell jewellery. The shell was used in combination with other materials. The catalogue of the exhibition says, "that the pearl is cut from a rare shell found in the West Indies, and, from its delicacy of color, it far surpasses the best and purest coral, while its brilliancy equals that of many gems. From its hardness, it is susceptible of a very high degree of polish, and it seems eminently adapted for use in jewellery, for which purpose it has not before been applied." It is a rare material, and there is considerable difficulty in manipulating it; but there is no doubt of its beauty, and that it looks well in combination with other jewellery and with the precious metals.

WOOD.

The ornaments in wood most known in this country are those made in bog-oak, of which large numbers are sold yearly at a very moderate price; not so moderate, however, as to preclude imitation. Side by side on the table is a brooch of bog-oak and a brooch and ear-rings of some hard wood, stained to resemble bog-oak, and looking at them it is difficult to tell which is which. There is a considerable difference in the price, however, the imitation being about five times less than the real. The imitation, however, gets brown in a very short time, while the oak always retains its color.

The bracelets and brooches of wood that are made in Scotland, are first of all turned, and are then highly varnished or enamelled, and colored according to the

pattern of some popular tartan. Oddly enough, as it seems to me, there is a considerable export of these goods to France.

JET AND ITS IMITATIONS.

Jet is a very beautiful material, found in the slaty rocks at Whitby, in Yorkshire. It is said to have been worked long before the time of the Danes. It is supposed to be, by Dr. Young, wood in a high state of bituminization. It is a material that makes admirable mourning jewellery, and it has a lustre and brightness which gives it the preference over bog-oak. I understand that Birmingham has taken up the manufacture of jet ornaments, that the various pieces of jet are worked at Whitby by hands in the employ of Birmingham manufacturers, and that the pieces are then sent to Birmingham to be mounted. Ebonite and vulcanite, both a compound of caoutchouc and sulphur, are among the imitations of it; another being a compound formed of a wood powder blackened, moulded, and hardened by a certain process. A large number of persons in the east-end of London gain a livelihood by the manufacture of vulcanite ornaments. The material is very workable, and not expensive, and women and children can help.

The vitreous imitations of jet are not, to me, particularly successful, but, as a manufacture, the English is better than the French, for this reason. The glass in the French is fastened to the metal backing only by shellac; the consequence is, that a slight blow will cause it to break off, and the heat of a room has been known to separate it. The English glass work is soldered to the metal, the glass having first of all a facing of some kind, and exept under very rough usage, it will wear very well. It is sometimes desirable to effect a combination between glass and metal, as in the case of some kind of buttons for instance, and some common kinds of brooches. The pieces of glass, having been moulded or pinched the required shape, are placed on an iron tray upon which is a metal foil upon which a flux has been previously applied. The tray is than placed in a furnace, and at a certain temperature, the glass and the metal foil fuse together, and enter into such perfect combination that, when broken, the metal and the glass still adhere to each other.

MACHINERY AND HAND LABOR.

I have said that machinery has done much for the cheap and rapid production of jewellery. Of course it is almost impossible that hand-work can be entirely dispensed with, especially if anything like a difficult ornamentation is attempted. Even in the commonest article, say a brooch or a locket, the pin has to be fastned by solder, the hinge has to be affixed, and, in the case of a chain, the fasteners at both ends have to be put on. What machinery can do is this, it can save labor in stamping, and punching, and working mathematically correct, as it always does, it can turn out two parts, as the cases of lockets or the links of a chain, so perfectly true to each other, that no cutting, or filing, or fitting is required. To give you an illustration of this, these two little watch wheels, which Mr. Streeter has given me, are so true to each other, and their cogs are so mathematically correct, that they fit one into the other, and become as it were one piece of metal. These wheels can be cut by thousands, and what is true of the first pattern is true of all the rest, and what is true of the whole wheel, is true of every cog; they can be turned round, fitted hap-hazard, yet are still true. So much for what machinery can do towards saving labor of this kind. No hand-work could possibly produce such a wheel as this in such a time and at such a cost. I believe I am right in saying that this wheel can be produced at a cost of threepence. In the case of trinkets, it can stamp out the parts of a locket so that it shall only require a pin to be inserted in a socket to make its manufacture complete, and this it can do for other things.

Here is a locket which has no hand-work whatever, about it; it is stamped out of one piece of metal; it has no hinges; it does not, of course, open, and the back and front are kept together by clamps, which are simply turned over.

It may be interesting, perhaps, if I go regularly through the manufacture of a brooch by hand, as followed by a working jeweller. Mr. E. Stokes has kindly enabled me to show you some of the appearances a plate of metal undergoes before it can come out in its complete form. Here is a plate of metal, and here is a die; this die, as you all, I have no doubt, know, is cut in steel by a class of work-

men who are called die-sinkers, but of whose work I need say nothing. The object of the workman is to get a perfect impression of this die upon the plate of metal. To obtain this, he manipulates the metal, and gradually works it down into the die bit by bit. Having worked at it for some little time, it is found necessary to anneal the plate, as it is called, for long continued hammering makes it brittle, and incapable of further extension. It is again heated, and allowed to cool slowly. This operation has to be repeated a number of times, during the process of taking the impression, and its various stages are represented here. This having been accomplished, the next step is to add any other parts that may be necessary, by soldering, and then the whole is placed in what is called "pickle," that is, a hot alkaline solution, which removes the effects of the fire, and then, if of common metal, it is gilt, and the parts that are intended to be bright are burnished.

This taking an impression from a die is done by machinery in precisely the same way, only the press acts instead of the repeated taps of the hammer; the whole piece is not stamped out at once, as many will think, but a portion at a time, and the same annealings take place. I believe I am right in saying that experiments are being made with a view to attaining, by a slow and equal pressure, the power of completing the stamp at one operation. Equal pressure is what is wanted. You will readily understand that, in forcing the metal into the die, it is very likely to be much thinner at the point of pressure than anywhere else. This is the great difficulty, which is not overcome even in hand-work. I may say that in making jewellery there is always a loss of metal in working. In filing, chasing, cutting, etc., the metal flies off in a fine powder; this falls upon the floor, and is carefully preserved, the sweepings of a jeweller's shop often being of great value. The working loss in gold is calculated to be one pennyweight per oz.; therefore, in estimating the price of jewellery, this has to be allowed for. In machine-made work, the liability to loss is greater than in hand-made, because the particles fly off to a greater distance, and are not so easy to collect. This difficulty is got over by placing a glass shade over the machine, which catches the particles and keeps them together.

The cutter by which the star shapes for lockets are cut out revolves at the rate of about 3,000 revolutions per minute. The value of such machine cutting is this, you get all the angles mathematically true, which it is almost impossible to get by hand, and this exactness in geometrical patterns, where the least inequality offends the educated eye, is very great.

I hold in my hand a piece of chain, which is, to my mind, a perfect triumph of machine work. It is a piece of common snake-chain, which may be seen in any jeweller's shop, and in common metal, may, I believe, be bought wholesale at about 4s. 6d. a yard. It is a marvellous piece of ingenuity. Its regularity, its flexibility, and the closeness of its manufacture is wonderful, and I think it may fairly rank amongst the highest productions of machinery. I believe I am right in saying that it is the work of a Mr. Holland, and that he has been able to keep the method of manufacture a secret to himself, and that all the snake-chains of this precise pattern are made by him. Any way, no one has yet been able to discover from an inspection of the chain, in what way it is made; and, pull it to pieces as you will, it defies scrutiny; and, as a distinguished manufacturer said to me the other day, "I have tried over and over again, but have failed, and I believe one might grow gray in trying." Mechanists may be able to give a shrewd guess as to the kind of machinery employed, but the combination they cannot guess. Let us hope that the secret, if it is possessed by Mr. Holland only, will not be lost when he is gone; for the pattern is not only one of the most popular, but certainly is one of the most pretty and useful. It has a few defects; for instance, it is easily snapped in two, and when once snapped it is unmendable, for it is the only pattern in which there is no solder.

If I cannot explain to you the manufacture of the snake-chain of Mr. Holland's invention, I can this, which is technically called a spiral chain. It is hand-made, and consists of two wires, with turned edges—a male and a female wire. These are bound round what is called a spit, the edges being turned towards each other. The elastic character which the finished work has, is caused, it will be

readily seen, by there being a space between the edges of the wires. The wider the wire the greater the elasticity. The varying width which this bracelet, for instance, has, is given by the spit, which is wider in the centre than it is at the ends. It will, therefore, puzzle some to know how the skip is removed; this is done by burning. When enough of the wire has been rolled, it is cast, spit and all, into the fire; the wood burns but the metal remains intact. It is an ingenious chain. I am not acquainted with the name of the inventor, but he certainly has enabled some very effective ornaments to be produced. There is another method of getting rid of the spit used in France, and possibly in England. The spit is formed of, metal D'Arcy I believe it is called, an alloy of bismuth and lead, which is fusible in boiling water. The chain is made as before, and the alloy is run out by applying heat.

A considerable saving of labor has been effected by the introduction into the trade of ready-made mountings for stones. These mountings are used, not only for the cheaper, but for the finer kinds of jewellery. The parts that go to make up this ear-ring, for instance, are cut out separately by machinery, and then soldered together. Another invention for the same purpose, by Mr. Ferre, consists of a strip of metal with a serrated edge; this is bent in the shape required, and the teeth are bent over the stones.

Now, by way of conclusion, let me give utterance to an idea that has come into my head with regard to this matter of personal adornment. I am not going to say that makers and sellers of sham jewellery are lowering the morals of the country. I will not say they aid and abet the actual lie of those who would have us believe their brass is gold, and I will not go so far as my friend, Dr. Dresser, who, in a paper read before us last year, asked if the destruction of Pompeii and the woes that have lately fallen upon our neighbors across the Cannel, were not due to their false quantities in decorative art. But I do mind me of a sentence of that quaint divine, Dr. Andrew Fuller, who said that, in the time of Elizabeth, a "lady would as soon have patiently digested a lie as have worn a false pearl." I am afraid this high regard for truth is not characteristic of the present generation. There is, on the contrary, a good deal of show and humbug about even ladies and gentlemen, and "all is not gold that glitters;" and it is possible that mock jewellery, false hair, pretended jewels, and other shams may blunt that keen sense of truth and right which distinguished our Saxon progenitors. At the same time, I am bound to admit that by the rapidity and cheapness of manufacture nowadays, things of beauty are placed before those who would never otherwise enjoy them, and perhaps, after all, as Mr. Wright, in the report I have alluded to says, "There is no valid reason why the factory girl should not display her gilt buckle and brooch of the same design as the golden one worn by the lady of the villa." Art may thus serve the community by cheapening the cost of the beautiful, and afford gratification to the humblest members of society, by superior designs reproduced in the cheapest possible form, and attainable by all.

Before I sit down, I must refer you to the specimens of jewellery upon the table. This case, lent by Mr. Streeter, contains some gold ornaments manufactured by machinery, the design being a *fac-simile* of various leaves of trees, the most delicate fibres being reproduced with a surprising fidelity. This diadem and necklace of entwining ivy is most graceful in design, and seems to me to display a great amount of artistic skill in the workmanship. These trinkets, that I have referred to during the evening, have been lent me by Mr. Silber, of Wood street, who very kindly allowed me to choose from his warehouse the representative ornaments of the French, German and English manufacture. I have taken the best and the commonest of each, and placed them side by side, so that you will be able to compare the workmanship and the designs of each of the great export countries, although they are here more as specimens of peculiar manufacture than that of artistic work.

This case of aluminium bronze ornaments, lent me by Mr. Pyke, who calls it Abyssinian gold, brings very clearly before you the perfection that may be arrived at in the manufacture of jewellery. Independently of the value of the material, the workmanship is of the highest order, and I do not think any praise is too high for the artistic skill displayed. If taken

as a representation of this particular branch of English manufacture, I do not think it can be beaten by any other country. It is such work as this that shows how the taste of the public is being gradually educated to the appreciation of beautiful forms. Such magnificent gold ornaments as those of Mr. Streeter are beyond the reach of the poor man, who may, however, have in base metal a very artistic article of adornment. It is this only which redeems "mock" jewellery from the vulgarity which one has learnt to consider as almost inseparable from sham. My best thanks are due to all these gentlemen for their kindness, as also to Mr. Stokes for the dies I have referred to.

ON TESTING THE VALUE OF UNGUENTS.

From the "Annual of the Royal School of Naval Architecture and Marine Engineering."

In this article it is intended to consider merely the unguents used for machinery, and therefore to confine the attention principally to those qualities which are essential for this purpose.

In testing unguents with a view of ascertaining both their absolute and relative values, it is necessary to fully bear in mind what an unguent really is, the use for which it is employed, and the particular qualities we should especially look for in it. First then, an unguent is some substance a thin film of which is capable of preventing the surfaces of two parts of a machine (working together) from coming into actual contact; next, the use of an unguent is to reduce the resistance due to friction—that is, with an unguent the friction should be less than what it would be were the two surfaces actually working in contact, and of course with the reduction of friction there will be a reduction of the wear and tear of the working parts; another use of an unguent is to assist in conducting away the heat which has been generated by the friction.

The quality of an unguent will depend in a great measure on the fulfilment of the above conditions. That is to say, the substance should possess sufficient viscidity to prevent the film being forced out by the pressure with which the two surfaces are kept together; and not enough viscidity to make the friction either equal to, or greater than, that caused by the surfaces themselves rubbing together. The substance, also, by its flowing away, should be able to take away the heat generated by the friction, and so prevent the temperature of the working parts being increased to an objectionable degree. To accomplish this last it must have sufficient fluidity to flow constantly, though slowly, through the bearings, etc., and also to remove any of the solid matter left on the decomposition or evaporation of any part of the unguent.

There are also other properties of unguents which will affect their quality and relative value—namely, their action, if any, on the material of which the surfaces are composed; the action of the atmosphere on them; and the facility with which they can be used in the instruments, or other means, employed for lubrication.

Another point to be borne in mind is the special purpose for which the unguent is to be employed; for example, a lubricant must generally be obtained which is adapted to the pressure by which the rubbing surfaces are kept together, as under a certain pressure (per unit of surface) the minimum friction will be given with one lubricant, and under another pressure with some other lubricant. In some cases an unguent must be provided suitable for the speed at which the machinery moves, as it has been found that a lubricant which will reduce the friction to a minimum at one speed will not so reduce it at another speed. Again, an unguent must sometimes be chosen to suit the material of which the surfaces are composed; for though, as a rule, the friction of two surfaces rubbing together depends on the unguent, and not on the nature of the material, still, in some cases, it is found that some particular lubricant is more suitable for certain surfaces than any other.

Of the substances fulfilling the conditions above specified, most belong to a class of bodies known as fats or oils, a large number of which are found to possess all the requisite qualities, in a greater or less degree, though some few other substances, such as water, graphite, etc.,

are occasionally used. These various bodies will, of course, vary in point of importance according to the special purpose for which each is to be employed.

The fats or oils used for lubrication are principally animal fats and vegetable fixed oils. Animal fats, though at ordinary temperatures more or less solid, may be regarded, both on account of their general properties and chemical constitution, as varieties of oil, and we shall therefore include them under the general term of solid oils. There are also animal *oils*, properly so called, as whale oil (commonly called train oil), spermaceti oil, etc. Most animal oils, being of a nature known as fixed oils, may be used for purposes of lubrication; but being generally solid at ordinary temperatures, they are principally employed for lubricating those parts of machines which work at high temperatures, which high temperature is not due to friction, but to some other cause; sometimes to the agent by which the machine works, as for instance, such parts of the steam-engine as the cylinder and slide-valve. The most common of the animal oils are:—Tallow, fat of sheep, oxen, and deer; lard, the fat of hogs; seal oil; whale oil; and spermaceti oil. Vegetable oils are very numerous, and most of them are fluid at the usual temperature, but very few can be used as lubricants, as it is necessary that oils so employed should be only those known as fixed oils, and they must be non-drying as well; the chief of these are olive oil, rape oil, almond oil, colza oil, cocoa-nut oil, and palm oil (the last two oils are soft solids at ordinary temperatures). The oils that are liquid at the usual temperature are used for machinery in general, where the working parts are to be kept at a low temperature, and when, of course, the employment of solid oils would be inadmissible. Mineral oils also are sometimes used as unguents.

In some few cases other bodies are used as lubricants, instead of oils; for example, water has been found to answer the purpose, where metal and wood, or metal and leather, are working together; and graphitte and steatite (the substance known as French chalk) have been lately used as the lubricating matter in steam packing. We may mention, in passing, that soapy unguents (composed of an oil, an alkali, and water) are used for temporary purposes; but as they are not generally used for machinery, we need not again refer to them.

Having briefly noticed the several points to which we must turn our attention with reference to unguents, their properties and qualities, we may now proceed to detail the observations which should be made on, and the means which may be employed for testing these various substances, with a view of ascertaining their values as lubricants.

Two sets of observations may be taken —viz., one on the nature and properties of the oil without the aid of machinery; and the second on the properties and qualities of the oil when practically used on machines. The first set will include the following observations:—The limit of temperature at which the oil ceases to be liquid, the effect of the atmosphere on an exposed thin film of the oil, the effect of the atmosphere on the oil in tanks or cans, and the effect of the oil on iron, brass, etc.; the question of *cost* might also be included under this head, but the consideration of this question must not be separated from the practical value. The second class of tests on the practical use of the oil in machinery should include: the manner in which the surfaces are working together, and the circumstances, in every detail, under which the parts are working; the quantity of oil used in a given time; the friction of the parts while in motion, or the *friction of motion;* and the friction of the parts when commencing to move, or the *friction of rest.*

Now to return to the first series of tests. We have first to note the temperature at which the oil ceases to be liquid, for it is requisite that the oil shall be in this condition at the temperature at which the machinery usually works, and, for machines in general, that will be the ordinary temperature of the atmosphere, for if the oil be not liquid, it is evident that the heat which is required, first to raise its temperature to the melting point, and afterwards to liquefy it, must be generated by the friction; and this heat will be in addition to that usually and unavoidably produced by friction when a liquid oil is used. This additional amount of heat represents, and is equivalent to, so much extra work to be expended in friction, for the useless purpose, so far as the efficiency of the machine is concerned, of melting the lubricant.

Next, with regard to the effect of the atmosphere on an exposed thin film of the oil. It has been previously stated that none but fixed and non-drying oils are used as unguents. By a fixed oil is meant one which is not volatile, or which cannot be obtained by the process of distillation; and by a non-drying oil, one which does not absorb oxygen, and so become hardened; is not liable to volatilization, and of which the more liquid portions do not, as in some oils, decompose and leave the more solid behind. It is evident, therefore, that if an oil were a perfectly fixed oil, and also perfectly non-drying, the atmosphere would have no effect upon it at all; but we know that *no* oil possesses these properties perfectly, from the fact that every oil has some peculiar odor, which proves that some part (probably an exceedingly minute quantity) of it evaporates, and that most oils, known as non-drying, on being exposed to the air for some time, eventually become dry. Therefore, what has really to be observed is the relative degree that oils fall short of being perfectly fixed and non-drying oils.* In making these observations, care should be taken that the oils do not gather dust from the atmosphere, and so interfere with the correctness of the results.

The next point is effect of the atmosphere on oils in tanks or cans. Of course the same effect will be produced as in the case of oils exposed in thin films, only that it will take a very much longer time; it is, therefore, simply a question as to how long the oil will retain its original properties. Again, it has been found that the oils which retain their fluid condition at low temperatures, when kept at a low temperature (near the freezing point of water, according to the description of oil) deposit a substance known as *stearin* or *margarin*, the two principles of which oil consists—viz., *olein*, the more liquid portion, and *stearin* or *margarin*, the more solid portion—becoming separated.

We have now to consider the effect of oils on iron, brass, etc., when in contact with these metals. Oils may act chemically on metals, either by their decomposition, when the metal will combine with one or more of the constituents of the oil then set free, or by having acid properties which will act directly on the metal. The action of an oil on copper or brass may be taken as an example of the former, and the action of certain oils on iron as an example of the latter, for when certain oils are used to protect iron from a moist atmosphere, to prevent oxidation, it has been found that they produce a chemical action on that metal, which is due to the acid properties they possess; but the greatest evil is brought about by the acid properties in oils, when, with iron and brass, or copper, in contact, a galvanic action is set up.

With the best oils very little effect is produced on the metals of which the working parts of machines are composed; therefore, if, after keeping any oils in contact with these metals for some considerable time, any decided action is noticed, such oils should be rejected for lubricants.

We will now proceed to the consideration of the second series of observations, the object of which is to ascertain the more immediate qualities of oils in their practical employment as lubricants. The first point which should be noted is the special purpose for which the lubricant is to be used—that is, the manner in which the parts of a machine are rubbing together; for instance, one part may be revolving within another with a motion either continuous or alternate in direction; or one part may be sliding within the other; or, again, the rubbing parts may be plane surfaces. There are other ways in which parts of machinery may work together, but the above are the principal.

Then the circumstances under which the rubbing surfaces are working should be noted—namely the pressure with which the surfaces are kept together; whether that pressure is uniform, as in ordinary shafting, or whether it is variable, as in cross-head guides, etc.; or if the pressure is suddenly applied at intervals, as in the bearings of a connecting-rod. Next, the speed at which the parts are moving should be observed; whether the speed is uniform or variable; whether the machine has intervals of rest; and with regard to plane surfaces working together, whether these are horizontal, vertical, or inclined.

Such observations as these, combined with those we shall mention presently, may be noted so as to ascertain whether a

* Oils in the process of drying become, first, of the consistency of liquid varnish or gum; and should any oil, after exposure for a moderate time, be found to become adhesive, it is useless as an unguent.

particular oil is adapted to a particular kind of machinery.

With regard to the remaining tests which have to be made—viz., the quantity of oil used in a given time, the friction of motion, and the friction of rest—there have been machines made for the special purpose of accurately ascertaining these points. These machines are usually called oil-testing machines; the working parts with which the oil is tried are generally a bearing of some sort, with a shaft or drum revolving within it, so that the manner in which one part is rubbing on the other cannot be varied. In some machines, however, experiments may be made with various speeds, and under different pressures keeping the surfaces together, and also with a variety of materials in the surfaces themselves. The testing is carried on as follows:—A thermometer is fixed to the bearing in such a manner that the temperature of the rubbing parts is obtained as nearly as possible. The lubricator is so constructed that the quantity of oil which flows into the bearing may be easily measured, means being taken also to vary the quantity supplied if necessary. To measure the friction, the whole or part of the bearing which is experimented on is free to revolve (within certain limits) with the shaft. It is carefully adjusted so as to be in equilibrium when the shaft is at rest, and when the shaft is revolving the friction will, of course, have a tendency to move the bearing round with the shaft, but this tendency to move is counteracted and the friction measured by a weight on the bearing acting in the opposite direction. This weight is made capable of being moved towards or from the centre of the shaft, so as to accurately balance the friction, and therefore measure force due to friction with the greatest nicety. Both the *friction of motion* and the *friction of rest* can be ascertained by this means. The results obtained from an oil-testing machine of proper construction are reliable, and therefore very valuable, although it must be borne in mind that these results are obtained only for a shaft revolving in a bearing; still, at the same time we must not forget that a large proportion of the working parts of most machinery consists of revolving shafts. However, if it is required to make further observations with parts working with different motions, or if trials have to be made where an oil-testing machine is not attainable, recourse may be had to machinery in general.

In trying oils on machinery in general, we must first select general bearings, or other working parts on which to make the experiments. The experiments may then be conducted in two ways: first, just sufficient oil should be used to prevent, if possible, the temperature of the working parts from rising too high, and the quantity should be accurately and periodically noted; the temperature also of the rubbing surfaces should be recorded at regular intervals; for the rise of temperature due to friction will be nearly proportional to the friction itself, and where the absolute friction cannot be measured, as is done by an oil-testing machine, the rise of temperature will be sufficiently approximate to show the relative values of the friction with the use of the various oils on trial. Secondly, the experiment may be conducted in this way: let a constant minimum quantity of each oil under trial be used in a unit of time, in turn on the same working parts, and note the rise of temperature in a certain interval of time in each case; for it has been already stated the rise of temperature will be *nearly* proportional to the friction. We say *nearly*, for although the heat given out by friction is exactly a *measure* of the friction itself, the temperature is not quite a measure of the heat. A more extensive and thorough practical trial of oils might be made in factories, with large engines, etc., where it is proposed to use any of them for machinery generally in this way. Let each oil to be tried be used in lubricating the entire plant of machinery for a definite period, noting the quantity used; and during that period take indicator diagrams of the driving engine, as frequently as necessary, to obtain the average power developed; note also the consumption of coal, or, what would be more accurate, the quantity of water evaporated by the boiler. Care should be taken too, that, as far as practicable, the amount of useful work done by the machinery should be exactly alike on all the trials, and this would be possible in many cases. Then, under such circumstances, the only work that will vary is that required to overcome the resistance due to friction, and the difference in the gross power developed by the driving engine will show the variation in the friction. One or two trials of

about two or three months' duration, with each kind of oil, would be a fair practical test. In conducting these trials with oils, ample time should be given for making all observations as complete as possible.

Lastly, with regard to the money value of oils. The question of first cost of oils will always be considered as a very important one, especially in large establishments where an immense quantity is used; but at the same time due consideration must be paid to the quantity required, and to the friction of the machinery when using these oils, bearing in mind that increased friction means increased wear and tear of machinery, and an increase of power for driving; or, in other words, an increase in cost of repairs and consumption of fuel. For instance, take the case of olive oil, which, though somewhat expensive, has been found to possess all the qualities required of an unguent, and to answer admirably for nearly all the purposes of lubrication. Suppose we wish to compare with it a cheaper oil (care being taken that we have *pure* olive oil, for it is sometimes adulterated with poppy oil, which is a drying oil, like linseed); after a fair trial with both oils, we *may* find that against a supposed saving with the cheap oil we have to compare the following items: a larger quantity of the cheaper oil consumed; additional outlay for repairs; a larger consumption of fuel, and perhaps also more labor to keep the machinery, etc., clean. And this greater expense in producing useful work may more than counterbalance the apparent saving in using the cheap oil, thus verifying the old proverb that "the dearest is sometimes the cheapest in the long run."

ON THE FUNDAMENTAL PRINCIPLE OF THE ACTION OF A PROPELLER.

From "The Annual of the Royal School of Naval Architecture and Marine Engineering."

The action of a propeller would be a question of considerable interest considered simply as a problem in theoretical mechanics, and its important practical applications render some knowledge of it indispensable to the Naval Architect and Marine Engineer. No one can have attempted to design or improve a propeller without having in his mind some idea of the mode of operation of a propelling instrument, and of the conditions of maximum efficiency to which it is subject. Yet it is only within the last few years that such knowledge has assumed such a definite form and been founded on such definite and widely-received principles, as to be entitled to the name and position of a theory. Even now the question is sometimes regarded as a very difficult one, incapable of treatment without a formidable array of mathematical symbols, so far as it is capable of treatment at all.

Unquestionably the problem has its difficulties, some of which have as yet been but imperfectly overcome, but we believe that the progress which has been made in its solution has been mainly due to the recognition of a principle in mechanics not more difficult to understand and apply than that principle familiarly known as the "Principle of Work," with which all engaged in practical work are so well acquainted. Inasmuch as M. Brin has recently called attention to the subject of propellers in a paper read at the last meeting of the Institution of Naval Architects, we have thought it might interest some readers of the "Annual," if we attempted to explain, in a manner as far as possible divested of mathematical forms and unfamiliar expressions, the principle alluded to, and to trace, as far as the limits of an article admit, its more important applications to the theory of propulsion. We shall do this by drawing a paralled between this principle and the principle of work, explaining step by step the analogies which exist between the two, and the differences which separate them, causing sometimes one and sometimes the other to be the more convenient in application. To thoughtful students of the orginal papers* little that we say will be new, yet perhaps even such may not be sorry to

*We refer especially to the "Mechanical Action of Propellers," by Professor Rankine, and to "Apparent Negative Slip," by Mr. Froude, read before the Institution of Naval Architects in 1865 and 1867 respectively.

see the question restated in a somewhat different form.

ELEMENTARY PRINCIPLES.

To commence at the beginning, let us first take the case of a body moving from rest in a straight line under the action of a constant force in that line, then we know that if P be that force, v the velocity of the body at the end of time t,

$$P\,t = m\,v,$$

where m is a constant, called the "mass" of the body, depending, first, on the size, secondly, on the density of the body, while the product $m\,v$ is called the momentum of the body. Thus the force multiplied by the *time during* which it acts is equal to the momentum of the body; and if the body have initially a given velocity, then we have only to substitute "change of momentum" for momentum.

But, further, we know that, if x be the space described, we have similarly

$$P\,x = \tfrac{1}{2}\,m\,v^2,$$

so that the force multiplied by the *space through* which it acts is equal to half the mass multiplied by the square of the velocity, or, as we commonly say, to half the vis viva of the body, while if the body have initially a given velocity, we say that the change in the half vis viva is equal to the above-mentioned product.

In the simple case, then, of a force acting on a body moving in its direction we see that the mechanical effect of a force may be measured in two ways: if it be considered as acting *through space* its measure is the change produced in the half vis viva of the body on which it acts, while if it be considered as acting *during time* its measure is the change in the momentum of the body which has been produced in the time. And these two ways of measuring force are not independent, but mutually convertible, the above equations being connected by the relation $x = \frac{1}{2}\,v\,t$—necessarily true whenever a point moves with uniformly increasing velocity quite irrespectively of any consideration of the cause of that motion—by means of which either of these equations may be deduced from the other.

In modern scientific works, forces are measured by the velocities they generate in bodies of given mass, but in practice forces are measured by units of weight such as pounds, so that the product $P\,x$ to which the familiar name of "work" belongs is measured in foot-pounds or foot-tons. Hence the force P is said to accumulate in the body on which it acts $P\,x$ foot-pounds of mechanical work which is stored up in the form of vis viva and reproduced again whenever the body is reduced to rest.

Now we have no similar name for the product $P\,t$, but we see at once that it depends on *time* and force just as $P\,x$ depends on *space* and force; hence it is properly measured in second-pounds, or second-tons, and we may now say that the force P accumulates $P\,t$ second-pounds of momentum in the body, all which must again be reproduced whenever the body is reduced to rest. If we had a name* for $P\,t$ the analogy would be perfect, and in fact the two cases are precisely parallel; for instance, just as we speak of $\frac{2\,g}{v^2}$ as the "height due to the velocity v," so we may with propriety—since

$$P\,t = W\,\frac{v}{g} - \text{call}\,\frac{v}{g}$$

the time due to the velocity v. And this analogy suggests that if we dwell too exclusively on the *space-effect* of force we may overlook important results obtainable by considering the *time-effect* of force. Following out this idea, let us now generalize, commencing with the

PRINCIPLE OF WORK.

Let us suppose any number of particles connected together in any way and acted on by any forces acting in any directions, then the work done by those forces as the particles move from one set of positions to another is spent in two ways: (1) in changing the half vis viva of the particles, (2) in overcoming their mutual actions. The half vis viva of the particles is simply the sum of the products formed by multiplying the mass of each particle by the half square of its velocity estimated *without reference to direction*, while the way in which work is spent in overcoming mutual actions is easily understood by imagining, the particles connected by elastic strings in which case it is plain that the work done in stretching the strings must be

*Sir W. Thomson has called the $\int P\,dt$ "the time integral", but this name is not very suitable for our purpose. For want of a name we are frequently obliged to use the word "force" where we really mean the "time integral," or else to restrict ourselves to the change which occurs in a unit of time.

considered as part of the effect produced by the work done by the external forces. In two cases—namely, that of a rigid body and that of a perfect incompressible and frictionless fluid—this second part does not exist, and the work done by the external forces is equal to the change in the half vis viva. In an actual fluid the present state of our knowledge respecting molecular action hardly permits us to say whether the work dissipated in "friction and shock" should be placed wholly in the first or partly also in the second class; we only know that the work done by the external forces must be equal to the half vis viva due to *visible* motions together with the work dissipated as above. This is the principle of work as applied in hydrodynamics, a principle of wide and well-known application; there is, however, this obstacle to its use—namely, that the amount of work dissipated in friction and shock is usually large and difficult to estimate. Thus the greater part of a work on hydraulics is taken up with the discussion of the "loss of head" by resistances of various kinds, a loss about which little is known except through direct experiment. In the theory of propulsion this obstacle is so serious that little or no progress has been made with the question by aid of the principle of work alone. Let us, therefore, now try and generalize our other principle, which we may call the

PRINCIPLE OF MOMENTUM.

First suppose a particle moving in any way under the action of a force constant in magnitude and direction, then the ordinary laws of motion tell us that the change of momentum *in the direction of the force* is equal to the product of the force and the time—that is, momentum, instead of being estimated like vis viva, irrespectively of direction, must always be estimated in the direction of the force we are considering. Next imagine two particles A and B connected together in any way, and acted on by a pair of forces constant in magnitude and direction; then since "Action and Reaction are equal and opposite," with whatsoever force A draws B in any direction, B will draw A in exactly the opposite, and hence it is easily conceived that whatever momentumthe mutual action of the particles generates in A in any direction, it will generate an exactly equal amount in the opposite direction in B, so that, if we understand by the accumulated momentum in any direction the sum of the momenta of A and B when moving in the same sense, and the difference when moving in the opposite sense, then that accumulated momentum is unaltered by mutual action, and is consequently equal to the product of the sum of the two forces and the time elapsed. And what is true of two forces acting on two particles is true of any set of particles whatever, connected in any way, and acted on by any forces; the accumulated momentum in any direction is always independent of mutual action, and if the forces have a constant resultant in any direction, the change in that accumulated momentum in any time is equal to the product of that resultant by that time. Conversely, if we observe that a certain change in the accumulated momentum of a system takes place in a given time, we infer just as certainly that a corresponding force must have operated to produce that change, as, when a certain change is observed in the vis viva of a system, we infer that a corresponding amount of work must have been done to effect that change. Such is the principle of momentum stated in a simple form suited to the problems we are about to consider, and its advantages are, (1) that it is true, irrespectively of mutual action; (2) that we do not require to know the motions of the particles completely, but only their resolved parts in a given direction. On the other hand, we must, in applying the principle, take care to consider all the forces which act on the system, and not merely *those which do work*, as in the case of the principle of work; for this reason, amongst others, this principle is not nearly so fruitful of important results in the greater number of mechanical problems as the principle of work; it is chiefly in hydrodynamical problems that it is of great value, and it must always be remembered that, so far from the principle being contradictory to the principle of work, on the contrary, the principle of work is frequently deduced from it in works on theoretical dynamics.*

* In his third corollary to his laws of motion, Newton explains what is to be understood by the total momentum of a system, and proves that it is independent of mutual actions. When the principle of the text is generalized by adapting it to the case of variable forces, and extending to couples, we obtain the six general equations which are placed at the commencement of modern works on the dynamics of a system of particles, and which simply express the equality which exists

Now the importance of the principle in hydrodynamics arises from the following considerations:—

It was explained above, that in estimating the total momentum of a system we must take into account the direction of motion of each of the moving particles, and hence it appears that if two equal particles move in opposite directions their total momentum is zero. Now cases of fluid motion are common in which for every particle moving in a given direction with a given velocity another equal particle exists, moving in exactly the opposite direction with that same velocity; this, for example, is the case in a complete wave length of a deep water rolling wave and in many other kinds of wave motion; it is also so when a fluid forms a whirlpool about a fixed axis; and thus it comes to pass that the resultant momentum of a fluid is often small, while its vis viva is great. And hence, whatever be the true nature of the process by which work is dissipated in a fluid by "shock," whether it be wholly due to infinitesimal whirlpools, or in part to some kind of mutual action between the particles, there can be little doubt that in estimating the momentum of a fluid mass we need only concern ourselves with the *visible* motions generated in the water without attempting to estimate those *invisible* motions which elude our senses, and the effects of which can only be obtained empirically.

We now proceed to examples, and our first example shall be that of a

JET OF WATER STRIKING A PLANE.

A jet of water strikes perpendicularly a plane of indefinite extent, what is the pressure on the plane?

If we follow the course of any particle, at first it is moving perpendicularly to the plane with velocity v (say), then it gradually diverges from the axis of the jet, and at length after the lapse of an unknown time, moves parallel to the plane—that is, its momentum perpendicularly to the plane gradually diminishes, and at length vanishes altogether. Let us now consider the change which takes place in the whole jet in a second; the number and velocity of the particles which at any instant are having their motion gradually changed are always the same, and the change, therefore, consists in the destruction of the momentum perpendicular to the plane of the quantity of water delivered by the jet in 1 sec. Multiply, therefore, the mass of a cubic ft. of water by the delivery in cubic ft. per 1 sec., and that again by v, the result will be the change of momentum in 1 sec., which, in conformity with our principle, must be the pressure on the plane. The result just obtained can also be derived from the principle of work, if the fluid be supposed frictionless, by an artifice which we have not space to point out, but we here see that it is equally true of a fluid with friction, the only supposition made being that the velocity of the fluid perpendicularly to the plane is wholly destroyed—that is, that nothing of the nature of a rebound takes place from the plane. This problem, which is of primary importance in the theory of hydraulic machines, will be found further developed in Rankine's "Steam Engine." We regret that our space will not permit us to give some examples of analogous problems,* many of which are of much interest; but as we are especially considering the theory of propellers, we pass on to questions more nearly concerning that theory; first, however, remarking that the above result has been tested by experiment and found to agree well with theoretical conclusions.†

VESSEL MOVING THROUGH THE WATER.

When a vessel is towed through the water by a rope, the tension of which is R, the work done by R in moving through a space x is R x, and this work is expended in producing visible motions in the water, due to adhesion, friction, or normal pressure, together with certain eddying motions, wholly or partly invisible, due to friction or improper formation of the vessel's surface. These two kinds of motion, together with any change in the motion of the vessel itself, represent a vis viva exactly equivalent to the work done by R.

between the rate of change of the momentum of the system and the impressed forces considered as acting along and about three given axes.

The couple form of the principle is useful in the theory of turbines, as Professor Rankine has shown in his work on the "Steam Engine and other Prime Movers."

*The formulæ placed by M. Brin at the head of his paper on the jet propeller can readily be obtained, but we do not insert them, as the problem of the jet propeller is so easily solved otherwise, and complex formulæ appear to us simply to divert attention from the real difficulties of the question.

† Many different experiments have been made, which will be found fully discussed in "Ruhlmann's Hydraulics," Leipsic, 1857.

Let us now suppose the vessel floating in a sea of finite extent, and let the tension of the rope act during a time t, then, if the resultant horizontal pressure of the finite boundaries of the sea be P, we must have (R—P) t as the momentum accumulated in sea and vessel during this time, for the only horizontal forces acting on the dynamical system are these two—namely, R and P. Now, though the assumption is not as obvious as it appears at first sight, we may assume with considerable probability that if the sea be of infinite extent, P=O, as it would be if all were at rest, and we shall then have Rt as the momentum accumulated in time t, just as R x was the vis viva accumulated through the space x. It may be asked whether this conclusion be true for an imperfect fluid, and the answer appears to be in the affirmative, only the "stiffer" the fluid the greater must be the sea to make the supposition P=O sufficiently approximate, so that in the limiting case of a solid body no extent of body, how great soever, is sufficient to make this hypothesis true. We therefore conclude *that the tension of the rope must be equal to the momentum generated in the sea and vessel during a unit of time.* To take an example: if a vessel of 8,000 tons displacement be towed by a rope the tension of which is 20 tons, the momentum generated at the end of 10 min. is 12,000 second-tons; if the vessel be moving uniformly, this amount of momentum is accummulated in the sea; if, on the contrary, it be initially at rest, and at the end of the 10 min. be moving at 10 ft. per 1 sec., then $\frac{8.000}{g}$ $\times$ 10 second-tons has been generated in the vessel, and there remains 12,000—$\frac{8.000}{g}$ $\times$ 10, say 9,500 second-tons, which has been generated in the sea. As has been previously stated, there is reason to believe that the momentum spoken of is represented simply by the visible motions of the water, and not also by those invisible motions which must be considered in applying the principle of work.

We need hardly say that we are not hereby enabled to find out what is the actual motion of each particle of water, nor how much water is affected by the passage of the ship. To obtain definite results from the principle of momentum, it is always necessary to know the initial and final motions of the water in some definite direction, and besides that, the quantity of water operated on must be known directly or indirectly.

If the vessel, instead of being towed, be propelled by paddles, screw, or other motor, worked by forces within the vessel itself, the momentum generated in sea and vessel is necessarily and always zero, and any forward momentum generated by the passage of the ship is necessarily exactly balanced by backward momentum generated by action of the propeller.

JET PROPELLER.—MAXIMUM EFFICIENCY OF ANY PROPELLER OPERATING ON UNDISTURBED WATER.

The simplest kind of propeller is known as the jet propeller, that kind of propeller in which the water is drawn from the sea by a centrifugal pump, and projected sternwards from orifices in the side of the vessel.

Here the water operated on is originally at rest; it is drawn into the ship and thereby caused to move with the velocity v, the speed of the ship, and is then projected sternwards out of the orifices with a velocity v, which we will suppose known. The real final velocity of the water is then evidently v—v, and if A be the joint sectional area of the orifices, A v is the quantity of water in cubic ft. per 1 sec. which passes through the orifices, and accordingly, if m be the mass of a cubic ft. of water, m A v (v—v) is the momentum accumulated every 1 sec. in water originally at rest. This can no more be done without the operation of a suitable sternward force than the corresponding amount of accumulated vis viva in the water can be generated without doing an equivalent amount of work, hence it follows that if P be that sternward force,

$$\mathrm{P} = m\,\mathrm{A}\,v\,(v-\mathrm{v}).$$

To understand how this sternward force exerted on the water operates, let us suppose first that, if the pump was not working, the water in the neighborhood of the orifices would be at rest, or, in other words, that the propeller operates on undisturbed water, then that sternward force operates *solely* through the sides of the passages which conduct the water from the orifices of entry to the orifices of discharge, for the external surface of the vessel will in this case most probably

have no sensible influence on the motion of the water, and therefore cannot exert any force on it. It is only the resultant sternward force which is above determined, and not the intensity of that force at any proposed point; it can, however, be seen without much difficulty that near the orifices of entry it is a forward force gradually urging the water forwards from its state of rest till at length it attains the velocity of the ship, while as the water approaches the orifices of discharge it becomes a sternward force, increasing the velocity of the water till finally it is projected from the orifices with velocity v. The difference between the sternward and forward forces is the resultant sternward force P, the magnitude of which has just been determined. In the case spoken of, when the propeller operates on undisturbed water, this force P must be exactly equal to the resistance of the ship, unless, indeed, the ship be not moving uniformly. Hence, if R be that resistance, it follows that

$$R = m A v (v - v).$$

Our result is independent of the nature and position of the orifices of entry, but we ought not to infer that these are matters of no importance. If these orifices are not so contrived as to admit the water without sensible shock, more water will be set in motion than actually enters the ship, a result equivalent to increasing the resistance of the ship; while if those orifices be placed at a point where the water is considerably disturbed by the passage of the ship, a complex effect is produced, which will be further referred to presently. Meanwhile we go on to consider what conclusions may be drawn from the result just obtained.

The velocity with which the water leaves the ship, is v—v, and the half vis viva accumulated in it is, therefore, $\frac{1}{2} m A v (v—v)^2$; if we add to this the useful work done in propelling the ship, we shall have $R v + \frac{1}{2} m A v (v—v)^2$, which is equal to $\frac{1}{2} m A v (v^2—v^2)$; and this must be the work done by the engines in a unit of time, irrespectively of friction and resistance of the water to being forced through the passages. Accordingly the efficiency of this propeller is $\frac{R v}{\frac{1}{2} m A v (v^2 - v^2)}$ that is $\frac{2 v}{v + v}$.

It is not difficult to perceive that this result applies to many other cases, and is, in fact, the maximum efficiency attainable by any propeller which operates in undisturbed water, for it was explained above that the propeller must necessarily generate a backward momentum equal to the resistance of the ship, while it is evident that the vis viva of the water proceeding from the propeller is wholly wasted; but that vis viva is obviously least for a given sternward velocity when the water is projected directly sternwards; accordingly if we neglect resistance of passages and friction, the jet propeller is a propeller of maximum efficiency; and, further, the efficiency of any propeller which operates on undisturbed water, and projects it sternwards with velocity v, must be as above $\frac{2 v}{v + v}$, supposing always that no power is wasted in any other way than in giving motion to the propeller race.

From this result we see that the efficiency approaches unity the nearer v approaches v, while referring to the formula $R = m A v (v—v)$, we see that, the smaller $v - v$ is, the greater must be A, and hence we conclude that, other things being equal, the efficiency of a propeller is greater the greater the quantity of water on which it operates. We shall have occasion to mention this hereafter.

Our space will not permit us to discuss the case where the water operated on is disturbed by the passage of the ship, and we besides do not wish in the present article to enter on questions which are not as yet completely understood. We merely remark in passing, that it is believed that in most cases the efficiency of a propeller is reduced by this cause. M. Brin, indeed, maintains in the paper above alluded to that the efficiency of the jet propeller can be made unity by placing the orifices of entry at the stern. This, however, does not seem possible, for to realize a propeller of efficiency unity we must take all the water set permanently in motion by the ship, and must project it backwards with such a velocity as to reduce it to rest. It is evident that if the ship and propeller together leave behind it any water possessing permanent motion, then all the accumulated work in that water will be wasted. The reasoning by which M. Brin obtains his result does not depend on any consideration of disturbed

water, but appears to assume that the pressure at the orifices of entry can never be less than the hydrostatic pressure due to the depth of the orifices, an assumption which amounts to supposing that no force is required to draw the water into the ship. In the other cases M. Brin* makes no similar assumption, and hence has arrived at a result agreeing with ours. We are certainly disposed to believe that the obvious view of the subject is the true one—namely, that the stern is the most unfavorable position for the orifices, but to give reasons would require a long discussion.

Some of the results of this section can be obtained by the principle of work alone, but we have not space to give the reasoning We now pass on to

FEATHERING PADDLES.

We have already said that the principle of momentum will not produce definite results unless we know independently the initial motion of the water, the final motion of the water, and the quantity of water operated on. For these data we must have recourse to observation in every case. In feathering paddles the obvious phenomena are the great streams of water issuing from the paddles. Initially this water is at rest, while finally it moves as is usually supposed with a velocity (v) equal to that of the paddle-floats, an assumption which apparently cannot be far from the truth. If, then, $Q=A\ v$ be the quantity of water operated on per 1 sec., the momentum accumulated in the streams in every second must be $m\ Q\ (v-v)$, which again, assuming that the water amidships would be at rest if the paddles were not working, must be equal to the resistance (R) of the ship. Moreover, the half vis viva of the streams will be $\frac{1}{2}\ m\ Q\ (v-v)^2$, and is consequently equal to $\frac{1}{2}\ R\ (v-v)$. Now the useful work done per 1 sec. is R v, and the power exerted by the engines, irrespectively of friction and other resistances to be mentioned presently, is $R\ v$, whence the power wasted is $R\ (v-v)$. Thus we see that the power wasted in producing that motion in the water which is necessary in order to obtain the required propelling reaction is only one-half the whole waste, a result characteristic of all propellers operating on the water with uniform velocity. One condition of maximum efficiency in a propeller is the same as that in any other hydraulic machine—namely, that during entrance to and the whole passage of the water through the machine, there should be as little "shock" as possible, a condition which is violated by paddles, as is shown by the violent dashing about which the water undergoes under their action. Our investigation shows that this "churning" absorbs as much work as is required to obtain the propelling reaction; and, in fact, more than as much is thus absorbed, for we have neglected the resistance to forcing the floats in and out of the water, a process giving rise to vertical forces not taken into account in the preceding investigation, but which increase the work done by the engines, so that the efficiency of paddles is somewhat less than $\frac{v}{v}$.

It may now be of some interest to compare roughly the efficiency of the jet propeller and feathering paddles, and for this purpose we shall suppose that the great technical difficulties which would arise from the use of large orifices have been overcome, so that our jet propeller sends back the same quantity of water with the same velocity as feathering paddles of 20 per cent. slip, for which the orifices must be somewhere about the same size as the paddle-floats. Then the power wasted by the paddles will be 10 per cent. in the race, and from 25 to 30 per cent. in "churning" the water and engine friction, while the jet propeller will waste 10 per cent. in the race, and at least 35 per cent. in engine friction and resistance of passages. Though it is generally agreed that the jet propeller has not yet been tried under favorable circumstances, we imagine most of our readers will agree with us in thinking 35 per cent. a low estimate. But it will be seen that even thus the jet propeller is not so efficient as paddles, while in practice the jet area must be reduced, when, as shown above, the comparison becomes yet more unfavorable. Besides the practical difficulties in the way of large orifices there is this objection, that if the orifices of discharge be placed under water they will add greatly to the resistance of the ship, while if they are placed clear of

* M. Brin's reasoning is not always easy to follow, but if the reader compares Section 7 of this Memoir with the mode by which he deduces equation (9) of Section 5 from equation (8) of the same section, it will be seen, we think, that something like this is assumed.

the water, work must be done to raise the water passing through them above the sea level; with large orifices the work so spent would be a very considerable item.

SCREW PROPELLER.

The screw propeller is vastly more complex in its action than either of the simple propellers we have been considering, for three reasons:—(1) the action is oblique instead of direct; (2) the velocity of each particle of water acted on by the propeller is not the same; (3) the screw always operates on water which has been previously disturbed by the passage of the ship, and the difficulties thus created are so serious that at present the problem cannot be said to have received complete solution. It would be impossible for us to enter on this question at the end of an article already too long; we shall therefore confine ourselves to a remark on oblique action which immediately follows from what has been said.

Oblique action is always, other things being equal, a cause of inefficiency in a propeller, as has been suffiiciently explained above, and it may be asked how this is consistent with the fact that the screw propeller is a practically efficient propeller. The principal and probably the only answer to this question is, that a screw of large size operates on a vastly greater body of water than any paddle-floats which could be put into the same vessel, and it has been shown above, that, other things being equal, the efficiency of a propeller is greater the more water passes through it. Yet no doubt it is conceivable that in some cases there might be less "churning" in an oblique acting propeller so as partially to balance the loss by lateral motions.

In conclusion, we must say that it is hardly possible to do justice to the subject within the limits of a few pages; we shall be content if we have succeeded in showing that the modern theory of propulsion is something more than a mere hypothesis, resting, as it does, on the secure basis of an old and well-known mechanical principle, interpreted and applied in a manner suitable to the problem under consideration.

THE THEORY OF THE HOT BLAST.

(*Continued from page 552.*)

Suppose now in this Guerche furnace, containing, probably, only 3,000 to 4,000 cubic ft., it were attempted to smelt Cleveland ore, which, so far as yield of iron and consumption of flux are concerned, nearly approaches that affording the results just given.

In order to prolong the contact between the ore of Yorkshire and the reducing gases, as well as to increase the deoxidizing power of the latter, probably not far short of 65 cwt. of fuel would be necessary to obtain a ton of iron. No less than 40 cwt. being thus expended in establishing the proper relations between the co-efficient of fusion and that of reduction.

There is, however, another method in making amends for this want of harmony between the two functions of the blast furnace. Instead of delaying the fusion of solids, and increasing the energy of the reducing gases by the addition of CO, the same object may be attained if contact is prolonged in a furnace of larger capacity.

In illustration of this mode of action, I will again quote from the experience and figures kindly communicated to me by my friend, Mr. Horton, of the Lilleshall Iron Company.

In furnaces having a height of 53 ft., driven with cold air, an ore poorer than the Scotch black band, and containing about 43 per cent. of iron, calcined, was smelted with about 40 cwt. of coke, affording another case of an ironstone more reducible than those which hitherto have formed the favorite basis of estimating the effects of the hot blast.

Here the available heat may be taken at fully 25,000 cwt. units beyond that which could possibly be absorbed in the process, and which, in consequence, must have escaped from the throat.

Mr. Horton, encouraged by the example of the Cleveland ironmasters, proceeded to add to the capacity of his fur-

naces. Having to deal with materials entirely different in character from those used in the neighborhood of Middlesbrough, this gentleman deemed it prudent to proceed with caution, and therefore contented himself with raising his furnaces to a height of 71 ft.

The result was most satisfactory, and at Lilleshall may be seen six cold blast furnaces, making good foundry iron with 27 or 28 cwt. of coke, which is fully as small a quantity as would have been required in the old furnaces of 53 ft. had they been blown with an air at 450 deg. C. (842 deg. F.)

Possibly, looking at the tender nature of the coke at Lilleshall, and the size of the ironstone, Mr. Horton may have been quite right in not venturing on the adoption of the dimensions found now so commonly on the banks of the Tees, where the coke is dense and the ore in large pieces. Were it possible, however, to treat the Shropshire minerals in furnace 80 or 85 ft. high, so far as fusion and reduction are concerned, I apprehend there is little doubt the coke consumption might be reduced to that of Guerche, viz., 25,000 cwt. to the ton of iron, for it is obvious with an escape of 25,000 cwt. units there is still a considerable margin for economizing.

Had such an alteration, as that just described as having been made at Lilleshall, been carried into effect before the introduction of the hot blast, even in the then state of knowledge of the theory of iron smelting, the inference would have been inevitable, that the advantage obtained by raising the furnace was solely due to its imperfect nature—in short, that just as the Stückofen was inferior to the first high blast furnace, so was the furnace of 53 ft. at Lilleshall inferior to that of 71 ft.

Like the discovery of Abraham Darby in using mineral fuel for iron smelting, it is impossible to overrate the value of the hot blast at the period of its first introduction. Indeed, I am not prepared to say that for the black band of Scotland, it may not have nearly as great a value still, due to some mechanical difficulties in its treatment, such as forcing the blast through a very high column composed of this mineral and raw coal, and which, therefore, may render a lower furnace necessary, unless when assisted by Mr. Ferrie's coking chambers. In this opinion I am guided by the alleged want of success experienced by the Scotch ironmasters, when they raised their furnaces in former years, and by the opposite results obtained by Mr. Ferrie.

Apart from any such impediments as those just mentioned, what I consider as beyond all doubt is, that the value of the hot blast at the period of its invention was, so far as any "extraordinary effect" is concerned, solely due to the defective nature of the furnaces then in use, and that when this is remedied, 1,000 units of heat in the blast can be as easily accounted for as a similar quantity derived from the combustion of fuel in the hearth.

We have only to appeal to the knowledge afforded at Lilleshall in verification of this statement. Foundry iron is there produced with cold air by, say, 27½ cwt. of coke. Let 12,000 heat units be thrown in with the blast, which are equivalent to 4 cwt. of coke burnt with air at 485 deg. C. to CO. This at once is a reduction of the fuel consumed to 23½ cwt., which is probably not far off the actual quantity furnace of 71 ft. would require.

Speaking from the accumulated knowledge respecting the action of iron smelting obtained in recent years, we have seen that valuable as the hot blast was when applied to furnaces of moderate height, it was far from remedying entirely the structural defect alluded to above, for it was not until those of the largest description had their capacity doubled, that something like the full economy in smelting the ore of Cleveland was reached.

Returning for a moment to the enlarged Lilleshall furnaces, we have seen that precisely the same object was secured, whether, as in their case, an addition to the size was the means employed, or the blast was heated. Exactly the same law holds good with the furnaces of the former moderate dimensions heated with air at 450 deg. C. They may be enlarged, as has been done in most cases in the North of England, or they may be retained of lesser dimensions, and fed with air at 600 deg. to 700 deg., according to the mode pursued at Consett.

The limit, or what I have already stated, and what, in a future section, I shall again state, I consider to be—the limit of economy, once reached, very large capacity and very highly heated blast simply tend to neutralize each other.

It may be urged that whether a certain number of heat units is communicated to the blast, and, rising upwards, is intercepted and returned downwards, or whether the same result is brought about by an increase of capacity in the furnace, the effect upon the temperature of the crucible will be the same, and that in each case, it may be supposed, the heat of the latter will be augmented.

Not having access to any furnace (close topped) using cold blast as would permit an accurate examination of the actual temperature of the escaping gases, after an addition to its capacity has been made, I have been unable to prove, by actual experiment, what the effect has been of such increase of size, and of comparing such results with those at furnaces of similar dimensions using hot air, both being engaged in smelting the same kind of ironstone. Under these circumstances, I have been compelled to make use of such data as I possess, which, unfortunately, are not the best fitted for the object in question, because the materials under treatment differed considerably in their nature.

The furnaces selected for the purpose were two at Cyfarthfa, 52 ft. high, one blown with cold air, and the other with its blast at 332 deg. C. (610 deg. F.) The latter, using fully 8 cwt. less fuel per ton of iron than the other, nevertheless, had its gases passing off 60 deg. C. (108 deg. F.) hotter than those of the cold blown furnace.

It was mentioned, in the present section, that waste of fuel in the blast furnace arose from a want of harmony between the operations of fusion and reduction, the latter not keeping pace with the former. I have shown how this was remedied by increasing the opportunity the reducing gases had for acting on the oxide of iron. This was effected by a prolongation of contact, obtained by enlarging the furnaces; but we have only to refer to those experiments which were undertaken for the purpose of ascertaining the laws which regulate the conduct of the substances met with in the process of smelting an ore of iron, to see that the shorter period of contact can be maintained, or even curtailed, provided the energy of the reducing agent is augmented. Thus in Exp. 36, while calcined Cleveland stone lost 37.3 per cent. of its oxygen in 8 hours, by being exposed to CO at a temperature of 410 deg. C. (770 deg. F), the same ore lost (Exp. 49) 63 per cent. at a dull red heat in the same time, and 90 per cent. (Exp. 50) was expelled in 3¾ hours, the temperature being that of bright redness.

I infer, therefore, that the improvement by the use of the hot blast, is not due to any additional heat reconveyed to the hearth, but that such heat is utilized in promoting the energy of the reducing gases in the upper zone, and having done this, it is carried off from the outlet of the furnace. The reasons have been mentioned to show it is unlikely that the temperature of the hearth is really sensibly increased, and also that a very small addition to that of the escaping gases greatly augments the power they possess of causing reduction. It seems to me, therefore, much more probable that the advantage derived from the use of heated air must be ascribed to the increased temperature in the upper region of the furnace by which the process of reduction is hastened in a corresponding ratio. In this way, although fusion goes on at an increased speed in the hearth of hot-blast furnaces, on account of the decreased quantity of fuel by which it is effected, as reduction experiences a still greater acceleration, the two operations are carried on in harmony, in point of time, with each other.

If, then, we take the case of a cold blast furnace of 52 ft., consuming any given quantity of coke per ton of its product, I say that the temperature of the hearth is the same as that of any hot blast furnace producing the same quality of metal, from the same materials, and that the action of reduction being too languid in comparison with the process of fusion, a loss of fuel is the result, in the manner already described, and that this loss may be remedied either by prolonging contact, or by increasing the energy of the reducing gases by communicating heat to the air used for effecting the combustion of the carbon in the hearth. Further I say that when no such want of harmony between the two branches of the process obtains, as in the case of the furnace at Guerche, no such stimulus as that afforded by the hot blast is required. From this latter statement it must not be concluded that no saving in fuel would accrue to a furnace using 25 cwt. of coke to the

ton of iron by the addition of a high temperature to the blast. The calories, however, so contributed, would be found to correspond, in all probability, very closely with those afforded by so much coke economized by the change.

I may be excused, if I parenthetically notice the great advantage to be derived from a perfect understanding of the fundamental principles which lie beneath a process so essentially chemical as that carried on in an iron furnace. It seems scarcely possible to imagine that had the ironmaster, before Neilson's time, been aware, and, being aware, had seriously considered, that in many cases, out of 133,000 calories actually evolved, he only beneficially applied 49,000, or about ⅓ of the whole, we should not have had to wait for the accidental observation of a thoughtful gas-works manager, before attempting to avoid part of the loss of 63 per cent. of his fuel, which might have been done by the simpler plan of increasing the size of the furnace, in which, if the remedy be not perfect, it is at least as much so as that effected by the hot blast itself.

Greatly curtailed in point of importance, as I deem the use of hot air to be, since the adoption of recent improvements, I would not have it supposed that it has to be regarded in any other light than that of a very powerful and valuable aid to the iron smelter. Its mode of application is so direct and simple that heat may be conveyed in greater or less quantity, as may be required, at once to the focus of most intense temperature, without waiting for a change in the materials, which requires some time before it reaches the tuyeres. This assistance, too, is afforded by a fuel, the escaping gases of which, in many cases, if not so applied, would be wasted. These attributes, even in their modified form of usefulness, will, in my opinion, insure for Neilson's discovery a lasting position in the science of iron metallurgy, and will preserve for his name an exalted place among the most illustrious of those who, by their ingenuity, have advanced the industrial resources, and, therefore, the national importance of their country.

ON THE EFFECT OF THE HOT BLAST ON THE QUALITY OF THE IRON.

Like many new inventions, the hot blast met with considerable opposition at the period of its introduction. In Scotland, including the coal used at the blowing engine, the waste incurred in coking the coal, and all other items, the reduction in the quantity of fuel often amounted to 75 per cent. According to M. Dufrenoy, the money value arising fron this source, and that derived from a diminution in the general working charges, from the increased make, amounted to £1 5s. 11d. per ton of iron, made with air heated to 322 deg. C. (611 deg. F.)

With the Scotch pig iron makers, this difference in cost bore down all resistance, and every establishment in that part of the kingdom was speedily blown with hot blast. Wales up to the period of Neilson's discovery, was, according to Dufrenoy, able to produce pig iron at a lower rate than any other locality in Great Britain. Unfortunately for the Principality, the mere act of heating the air completely changed the aspect of affairs, for while this modification of the manufacture was followed by a saving of 26s. per ton in Scotland, something like 1s. 8d. was all the benefit its adoption was, according to the French engineer, able to afford to the Welsh ironmaster.

The Glasgow makers enjoyed immense advantages in the possession of their cheap and rich ironstone, but unfortunately, these were in a great measure, neutralized by its refractory nature when smelted in small furnaces (50 ft.) with cold air, a difficulty which involved the consumption of a large quantity of fuel, raised at a higher price than that of the Welsh coalfield. This objection was remedied by the addition of 600 deg F. to the blast.

In Wales, on the other hand, the ironstone was poor, but easily smelted; the coal was cheap (3s. 7d. per ton, Dufrenoy states), rich in carbon so that 50 to 54 cwt. were able to produce a ton of metal. This quantity could only, it was estimated, be reduced 17 cwt. by the use of the hot blast, from which had to be deducted 6 cwt. consumed in the heating apparatus, leaving a net gain of 11 cwt., equal to the saving of 1s. 8d. per ton, of which 1s. had to fall to the share of the patentee.

After some unsuccessful litigation in disputing the legal position of Mr. Neilson, many of the Welsh ironmasters discontinued the practice of heating the blast, it being pretended that the trifling saving

in cost was more than swallowed up by the inferior quality of the iron made by its means.

However sincere these manufacturers may have been at the time in question, further experience has modified their ideas, for at the present day by far the larger number of furnaces in Wales is blown with hot air.

It is now upwards of forty years since Neilson patented his discovery, and it is not a little remarkable that this question of quality cannot be considered as entirely settled yet. If the matter had to be judged by the acts of the majority of the manufacturers, then undoubtedly it might be inferred that the present cases, so few are they, where cold blast is still adhered to, might be regarded as the last signs of life in a struggle against speedy extinction. Large, however as this preponderance of opinion may be in favor of hot air, it has the objection, it may be urged, of being entertained by those who may be supposed to prefer its use on account of the cheapness it has been the means of introducing into their process, and the great command it gives over the operation.

With every wish to deal fairly with the disputed point of quality, its decision is surrounded with much difficulty, and is one which requires great experience, before any individual is justified in speaking with the necessary confidence even on facts capable of more speedy demonstration than those appertaining more immediately to the use and durability of the product. In illustration of this, I may observe on referring to some early notebooks of visits to the Welsh works, that the opinion was then pretty generally entertained that the whole of the advantages obtained in the blast furnace by the use of hot air was, by the waste of iron and defective quality, lost in the forge and mill.

The present generation, however, as a rule, has turned its back on the creed of its predecessor, and the advantages of hot blast, at all events as a matter of economy, are, in our time, universaly admitted. As regards the alleged loss in the process of converting the pig into malleable iron, I have the indisputable authority of my friend, Mr. Menelaus, of the Dowlais Works, for stating that this is a mere illusion, and that small, comparatively speaking, as the saving of fuel in the blast furnace is in Wales (about 15 cwt.), the advantages of hot air cannot be denied by any one who has paid proper attention to the subject. This it must be recollected, is, of course, not a carelessly adopted view, but one which is the result of comparing whole years' operations conducted under the two systems.

During the recent visit of the Iron and Steel Institute to Staffordshire, I made the subject a matter of constant inquiry. I cannot say the answers received were universally in one direction, but there is no manner of doubt the large preponderance of opinion, and this from makers of immense experience, is, that from the same materials there is no appreciable difference between hot and cold blast pig, nor in the malleable iron afforded by the two kinds of metal.

My experience in foreign countries leads me to believe that this is the view entertained by the great majority of those producers of the fine descriptions of charcoal iron, whose position in the market is entirely dependent upon the world-wide reputation of their limited make. With few exceptions, I found these Continental manufacturers had applied hot air to their furnaces; as, for example, in Norway and Sweden, when treating the pure magnetic oxides of these countries, in Styria and Carinthia, for smelting the fine spathose ore of Eisenerz and Lölling, and at Fullonica, when using the specular ore from the neighboring island of Elba.

At Dannemora, it is true, they adhere to cold air, on the ground, as I was informed that the quality of their well-known brand had suffered by an attempt to use hot air.

Professor Tunner * on the other hand, who has had large experience with the manufacture of the pure charcoal iron at Eisenerz, asserts positively that deterioration is no necessary consequence of the use of hot blast.

When such very minute quantities of certain substances, such as P, S, Si, etc., are known to be capable of affecting in an unmistakable manner the properties of iron in which they occur, it is, perhaps, an act of over-refinement to reason upon their being present in greater or less amount, from our presumed acquaintance with the

* Russland's Montan Industrie insbesondere dersen Eisenwesen. Leipsig, 1871.

nature of the smelting process, when carried on by means of air heated or otherwise.

It may be urged, and perhaps reasonably so, that our knowledge of this subject is too limited to deal satisfactorily with so delicate a matter as that in question; at the same time we must make the best use we can of the information we possess, and the argument based thereon must be judged accordingly.

Viewing the action of the blast furnace comprehensively, I have regarded the actual work done as performed identically in the same manner, whether the air is used hot or cold. Thus, in the Lilleshall 71 ft. furnaces, we have the combustion of about 28 cwt. of coke, affording the necessary heat for smelting iron from an ironstone yielding 40 to 43 per cent., by giving the gases time enough to become saturated with O, and so to communicate their sensible heat to the descending materials, that when the latter reached the tuyeres the store of heat they contained, added to that evolved by the combustion of the fuel, sufficed for the required duty, without any heat being communicated to the blast. If the furnace, instead of having a height of 71 ft., had only 48, the work was inefficiently performed, and had either to be supplemented by the hot blast or by the consumption of a larger quantity of fuel in the manner already explained. By an increase of capacity and the use of hot air, a further economy of fuel may be effected, and this continues until the gases are fully saturated with oxygen.

In effect, then, as has been already stated, for a similar quality of iron, an identity of temperature ought to be found in every furnace, whether the air which enters it is hot or cold. If this be so, then in the matter of temperature there is no reason why iron made in either way should differ materially.

If, on the other hand, as has been and is often alleged, the effect of heated air is to deteriorate the quality of the pig iron, we might reasonably expect that this deterioration would keep some kind of pace with the elevation of temperature conferred on the blast.

In comparing hot with cold blast iron, I speak with hesitation, from my want of experience with the latter, but in dealing with iron made in furnaces blown with air at about 350 deg. C. (662 deg. F.) up to 500 deg. C. (932 deg. F.), I labor under no such disadvantage. I may, therefore, confidently state from my own personal acquaintance with both, that the quality of the product has in no way suffered by the change from the lower to the higher of these temperatures of blast. Indeed, I may go further, and give it as my own opinion that there has been an actual improvement, which I attribute to the use of a less quantity of fuel, for, if reference is made to Section 35, on the behavior of P and S in the blast furnace, it will be seen there is an appreciable quantity of both these elements in the coke. Anything, therefore, which lessens the extent to which these acknowledged hurtful ingredients enter the furnace, must be beneficial, and one cannot be surprised that the iron has not suffered by raising the temperature of the blast, accompanied, as this has been, by a diminution in the quantity of fuel.

Looking back at the figures contained in the section mentioned above, it will be seen that the phosphorus entering the furnace, when using hot air, for each 100 parts of iron produced, amounted to 1.578, and the sulphur to 4.456. Were this furnace using 3 tons of coke per ton of iron, the phosphorus would be raised to 2.055, and the sulphur to 7.3 parts per 100 of pig.

These arguments, based on the action of the blast furnace, so far as they go, would point to the conclusion that hot blast, far from acting hurtfully on the iron smelted by its aid, will produce a marked improvement by the change in its temperature. At the same time, however, we must not overlook the fact that in the hearth of the blast furnace there is constantly occurring a series of very complicated, and, perhaps, not very well understood, chemical changes, which have been touched upon when speaking in Sections 26 and 34, on the generation and decomposition of certain cyanogen salts. Whether or not slight changes in local temperature may affect the order of chemical action, which appears very active near the tuyeres, it is impossible, in our present state of knowledge, to say.

The experience in the manufacture of Bessemer steel affords some information to guide us in the consideration of this intricate problem now under consideration. If a sample of pig is deliver-

ed to the bar iron maker, containing a large percentage of phosphorus, the action of the puddling furnace removes by far the greater proportion of this substance.

Exp. 752. A specimen of pig iron was ascertained to have associated with it

P 1.33 per cent.
S .158 "

the puddled iron made from it contained, of P, .29 per cent.; and of S, a mere trace.

Exp. 753. A second sample of pig iron, containing about 1½ per cent. of P, yielded a puddled bar, giving only .33 per cent. of this substance.

In the Bessemer converter, no such removal of phosphorus takes place, and as its presence in quantity amounting to less than one-tenth per cent. is fatal, the steel-maker has no alternative but to employ pig iron almost entirely free from this element. Sulphur, too, is equally shunned by the producer of Bessemer steel. Now if the action of hot air, in the blast furnace, tended in any way to concentrate the quantity of either phosphorus or sulphur in pig iron, it is clear its use would be more carefully avoided in the manufacture of that intended for the steel works than that destined for the manufacture of bar iron, inasmuch as the puddling process is capable of removing partially, at all events, the phosphorus, which is not the case with the Bessemer converter. This view of the question, of course, confines the cause of deterioration to sulphur and phosphorus. It is possible that some other ingredients may, by their presence, prejudicially affect the quality of iron, such, for example as silicon, but I am not aware that those who advocate the use of cold blast have ever succeeded in demonstrating that the superiority of iron, so smelted, was indebted for its alleged higher excellence to the absence of any particular ingredient or ingredients found in metal produced with hot air.

At the present time, when the relative merits of the two systems of manufacture are compared, reference is very generally made to the high character of certain well-known brands of iron, which being produced exclusively by means of cold blast, are regarded as affording incontrovertible proof of the superiority possessed by the ancient mode of smelting.

It is almost superfluous to say that it is in the highest degree unphilosophical to institute any comparison between hot and cold blast iron, unless in each case the minerals are precisely the same. To some extent this has been done, and it would appear that, according to the experiments of Fairbairn and Hodgkinson, already referred to, when the hot blast was applied to the minerals used at the Devon and other iron-works, there was an evident improvement in the strength of the pig iron.

At that period too little importance was attached to the chemical constitution of pig iron to have prompted any one to ascertain, by actual examination, whether any change in this respect had been induced by heating the air, and at the present day it is, so far as my inquiries go, impossible to obtain specimens of hot and cold blast iron smelted from exactly the same materials.

The nearest approach I have been able to make to this is afforded by the assistance of my friend, Mr. Walter Williams, the well-known Staffordshire ironmaster, and even here, the specimens are far from being all that is to be desired.

The cold blast iron was the produce of the Staffordshire clay ironstone, smelted with South Staffordshire coke, and with the Dudley limestone as a flux. The hot blast iron was obtained from the same Staffordshire claystone, mixed with one-sixth North Staffordshire black band, and one-sixth red hæmatite. The limestone employed in this case was from Wales, but the fuel used was the same as in the cold blast furnace. There were thus two important deviations from identity in the materials—the ore in the hot blast furnace contained one-third of hæmatite and black band, which were not present in that blown with cold air, and the limestone was different.

So far, however, as phosphorus is concerned, as the red ore is free from this ingredient, the sixth part of black band is the only source likely to bring any addition to this element, unless the flux from Wales is richer in P than that from Dudley.

Neither of these possible causes of contamination, however, have added, practically, either to the amount of phosphorus or sulphur contained in the hot blast iron, as may be seen from the following analyses, carefully done by my present assistant, Dr. Watson. Both samples were No. 3 in quality.

	Exp. 754. Cold blast.		Exp. 755. Hot blast.	
Fe	93.761		92.201	
C. graphite	3.062	3.405	2.568	3.161
combined	.343		.593	
Si	1.025		2.080	
S	.077		.065	
P	.663		.686	
Mn	.819		1.549	
	99.750		99.742	

In these experiments, there is a considerably larger quantity of Si in the iron produced by the hot, than by the cold blast furnace. In examining some of the analyses quoted in "Watt's Dictionary of Chemistry," the Si, in some cold blast iron, exceeds even the quantity given above; thus, in specimens of Dean Forest iron, made with cold air, 2.34 and 2.10 per cent. are given as the content of Si. Knowing from my own experience, however, how irregular the quantity of Si is in metal made in our own furnaces, blown with heated air, I was not disposed to attach much importance to this; nevertheless, other pigs of the same Staffordshire iron were sampled, and these, on trial, gave results which confirmed my opinion on the uncertainty as to the existence of Si in definite quantities.

	Cold blast.
Exp. 756. No. 2 iron, Si %	1.446
" 757. " " "	1.294
	Hot blast.
Exp. 758. No. 2 iron Si %	2.521
" 759. " " "	1.948

The only other notable difference between the two kinds of iron was the larger proportion of manganese in that made by hot blast. The presence of this substance was more likely to be an advantage than otherwise, but, to see whether its larger presence was accidental or not, further trials were made:—

	Cold blast.
Exp. 760. No. 2 iron, Mn %	1.060
" 761. " 4 " "	.953
	Hot blast.
Exp. 762. No. 2 iron, Mn %	1.726
" 763. " 4 " "	1.253

These numbers indicate that the metal, in question, occurs in larger quantity in hot blast iron, made of the minerals already specified, than is found in cold blast iron, from a mixture of ore of a somewhat different character.

I have in vain sought to connect the alleged superiority in quality, said to be enjoyed by iron manufactured with cold air, with any freedom from those substances generally considered as affecting prejudicially the character of pig iron. Of course, in them, as in all iron, hot as well as cold blast, we are pretty safe in asserting that excessive quantities of Si, P, or S, are hurtful, but on referring to a list of analyses in Bauerman's work on the "Metallurgy of Iron," it will be found that certain highly esteemed brands of cold blast iron appear to contain more of these substances than do others much less favorably known in the market.

Upon one occasion, the subject was made one of direct experiment at the Clarence Works. A furnace, about to be extinguished, was blown with cold air for a short time, the burden of ironstone, of course, being reduced to meet the change of circumstances. The trial was made some years ago, and the pig iron not having been submitted to analysis, I cannot speak as to its composition; but so far as the quality of bar iron it afforded is concerned, I know positively there was not the slightest trace of improvement.

It is almost needless to observe, that a belief in the absence of any advantage in the quality of iron produced by one mode of manufacture or another, does not involve any doubt as to the excellence of the produce of certain works which happen to be made by means of either; all that is intended to be conveyed by the general tenor of the present remarks is, that it scarcely has been satisfactorily proved that the excellence in question is really due to the temperature of the blast used in the smelting process. I have been given to understand that, in some establishments, making high-class iron, when a furnace, worked with cold blast, is driven so as to produce above 90 tons a week, an unmistakable deterioration in the quality of the bars obtained from pig iron manifests itself. Acceleration alone, in the speed of driving, may of itself give rise to an increase in the intensity of temperature evolved from a given quantity of carbon; but, at the same time, it is much more likely that the depreciation in quality, if it occurs, is due to a reduction in the actual heat of the hearth, which will be caused by a portion of the reduction being effected so low down in the furnace that the CO_2 dissolving C diminishes the weight of coke for combustion at the tuyeres, which, of course, will be followed by a lowering of temperature.

It might be inferred that when the

problem to be solved was the mere determination of certain physical properties, there ought to be no difficulty in ascertaining the relative power of resistance possessed in every conceivable direction by iron, cast as well as wrought.

All this has been done, and well done, at a very early period by Fairbairn and Hodgkinson, at the request of the British Association for the Advancement of Science. According to the report of these gentlemen, results were obtained of a somewhat unexpected nature; at all events, they certainly do not coincide with the relative estimation in which certain brands of iron were held, and continue to be held, in the market. The following figures are taken from one of their tables:

	Tensile strength per square inch of section in tons.	Crushing strength per square inch of section in tons.
Low Moor No. 1, cold blast	5.667	27.003
" No. 2, "	6.901	42.324
Bowling No. 2, "	6.032	33.507
Clyde iron No. 1, hot blast.....	7.198	40.535
" No. 2 "	7.949	47.326
" No. 3 "	10.477	47.338

The following table contains the data of different makes of pig iron manufactured by hot and cold blast, as determined by

	Carron, No. 2.	Devon, No. 2.	Buffery. No. 1.	Coed-Talon No.2.	Carron, No. 3.
Tensile strength	809	....	769	884	1,250
Compressive do.	1,020	....	925	1,012	1,156
Transverse do.	991	1,417	931	....	....
Power to resist impact	1,005	2,786	963	....	....
Transverse strength of inch square bars	973	1,199	942	....	....
Ultimate deflection do. in inches	1,018	1,380	1,058	....	....
Modulus of elasticity per square inch	931	991	893	....	....
Specific gravity	997	991	989	1,002	989

the same authorities as the preceding, in which the ratio between the two is given, cold blast being represented by 1,000. From these it would appear some irons are improved, and others are deteriorated in quality.

More recently, Mr. Kirkaldy has bestowed much attention on the strength of iron and steel, and the results of his investigations have been published.* From these the following numbers have been extracted to show that the more expensive irons do not exhibit a corresponding power of resistance. The specimens, Mr. Kirkaldy states, were obtained promiscuously from merchants' and engineers' stores, and in each case a rolled bar, 1 in. in diameter, was taken :—

BRAND.	Number of expts. of each.	Breaking weight per sq. in. of original area.		
		Lowest.	Highest.	Mean.
		Lbs.	Lbs.	Lbs.
Low Moor	4	59,320	65,166	61,798
Bowling	4	58,678	65,701	62,404
Bradley	4	56.004	58,036	57,216
Govan (Scotch)	4	57,738	59,726	58,746
Govan (Scotch) B. Best	4	60,069	66,363	62,849

Later still, M. Knut Styffe, the Director of the Royal Technological Institute of Stockholm, by order of the Government, undertook a series of investigations, which are recorded in a book on the "Elasticity, Extensibility, and Tensile Strength of Iron and Steel."† In this book, information of temperature at which fracture took place, and the carbon and phosphorus in the bars are given :

*"Experiments on Wrought Iron and Steel," 1863.
†Translation by C. P. Sandberg. By Murray, London, 1859.

BRAND.	Per cent.		Diameter of round bar	Temperature of bar, F.	Breaking weight per sq. in of original area.
	Carbon.	Phosphorus.			
			In.		Tons.
Low Moor (cold blast)	.21	.068	.465	- 32	27.35
" " "	"	"	"	+ 68	25.21
" " "	"	"	"	+ 59	29.10
" " "	"	"	"	+ 328	29.62
Middlesbro' (hot blast)	.07	.250	.581	- 40	27.44
" " "	....	....	....	+ 57	25.81
" " "	....	....	....	+ 60	23.58
" " "	....	....	....	+ 59	26.46
" " "	....	....	....	+ 318	31.12

The pages from which the preceding figures are extracted contain much information which would be out of place in such a work as the present.

My object has not been to compare the relative value of different kinds of iron, but to show how difficult it appears to be to prove the resisting power of either cast or wrought iron by mere experiment.

It must be remembered that the researches which gave the results just quoted, by no means represent the conditions of actual use. A cube or cylinder of cast iron may have a high tensile or compressive strength, but from excessive contraction in cooling in a large casting, may be in such an unequal state of tension as to break on concussion. In like manner, bar iron may, from causes our present state of knowledge does not enable us to explain, have great tensile strength, and yet be less able than others to resist those violent shocks to which in many cases it is exposed.

All this goes to prove that it is long experience alone which secures, and properly secures, for any particular mark that preference which commands a high price in the market, and this position it necessarily maintains against the produce of any less well-known manufacturer, who, nevertheless, may possibly turn out an article in all respects equal to that of his better-known rival.

My intention in this section, however, is not with this aspect of the question. It is simply to express the opinion that no satisfactory proofs have been published to show that the use of hot blast is attended with hurtful effects on iron produced by its means, while many manufacturers, well known for the quality of their make when cold blast alone was employed, have commenced the use of hot air without injury to the character of their iron; and further, that we have the evidence of authorities like Professor Turner in favor of the view, that whether iron is smelted by heat intercepted in the upper part of the furnace, or by fresh heat added to the blast, the resulting temperature in the hearth, I maintain, being, in all probability, the same in each case, is immaterial so far as the nature of the product is concerned.

A NAVIGABLE BALLOON.

From "Engineering."

The trial of M. Dupuy de Lôme's balloon, has certainly taken the importance of a scientific event in Paris. The construction of this aërial machine, starts with the principle, that to obtain a navigable balloon, the two following conditions must be complied with:

1st. The permanence of the form of the balloon, without any sensible undulation of its surface.

2d. Obtaining a horizontal axis of least resistance in a direction parallel to the propelling force.

The permanence of force is assured by a fan carried in the car, and put in communication by a tube with a small balloon

placed within the large one at its lowest part. The volume of this small balloon is one-tenth of that of the large one. It is furnished with a valve opening both within and without, and regulated by springs. The large balloon is provided with two hanging tubes open to the air, and falling for a distance of 25 ft. from the lower part of the balloon. The inflation of the little balloon causes the hydrogen to fall more or less in the hanging tubes, but never sufficiently to force it out of their open ends.

To obtain a horizontal plane of least resistance, the form given to the balloon was that developed by the arc of a circle turning around its chord, and in which the versed sine was nearly one-fifth of the length of the chord.

The following are the principal dimensions of the balloon:

	ft.	in.
Total length from out to out	118	6
Greatest diameter	48	9
Cubic contents	122,000	0
Total height from top of balloon to bottom of the car	95	6
Length of the car	41	3
Greatest width of the car	10	8
Diameter of screw	29	6
Pitch of screw	26	2

Ascensional force:	Tons.
With small balloon, not inflated	3.799
" " inflated	3.419
Number of revolutions of screw per minute to obtain a speed of 5 miles an hour	21
Time required to fill the small balloon by aid of the fan	15 minutes.

The upper portion of the balloon is covered with an envelope of fabric, which supports the car by a zone placed around the centre of the body. This envelope is then continued below the upper half until it covers about three-fourths of the body. Below the envelope, and attached in a similar manner, is a second zone within the first one, having the form of a cone tangential to the sides of the balloon. The summit of this cone serves to attach the cordage by which the car is sustained.

The rudder consists of a triangular sail placed beneath the balloon and near the rear, and it is kept in position at the bottom by a horizontal yard 19 ft. 8 in. long, turning around a pivot on its forward extremity. The height of this sail is 16 ft. 4 in., and its surface 161 sq. ft. Two ropes for working the rudder extend forward to the seat of the steerer, who has before him a compass fixed to the car, the central part of which is large enough to carry a crew of 14 men. The forward and aft parts are formed with a framing of bamboo.

The screw is carried by the car. The shaft can be easily lifted from the rear, and thrown upon a forward support, so that no damage can arise to it, either on departure or arrival. The screw is driven by four men, or by eight men working at a capstan. The gas-escape valves, of which there are two, are placed at the top of the balloon, immediately over the pendent tubes, before spoken of, and through which the cords for working the valves pass into the car. The balloon is made of white silk, weighing about 7 oz. per sq. yard, with 7 thicknesses of caoutchouc superimposed; the envelope also is of white silk. The joints are so arranged that they are stronger than the material itself. On the inner face, three coats of varnish were applied, formed of gelatine, glycerine, pyroligneous acid, and of tannin. Such a varnish is impermeable to hydrogen.

The balloon, properly called, weighs about half a ton, and the total weight of the whole machine is 1.753 tons. The crew, luggage, provisions, instruments, etc., weigh 1.446 tons. Of ballast $\frac{3}{4}$ds of a ton are taken. Collectively, these figures give 3.85 tons, equal to the full ascensional power at the ground level.

M. Dupuy de Lôme had calculated that, with a speed of 5 miles an hour, the resistance of the balloon in the direction of its main axis, would be 24.26 lbs., and that the speed of the screw should be 21 revolutions per min. to overcome this resistance. This speed could be easily obtained by four men working for half an hour, and being relieved at the end of that time by four others; with the eight men working together at a capstan 27 or 28 revolutions could be obtained, which would give a speed of about 8 miles an hour.

The stability assured by the system of suspension adopted, is such that even under the maximum effort of eight men working the screw, the equilibrium was only disturbed half a degree, and a man in walking from one end of the car to the other only affected it by half a degree.

The apparatus for producing the hydrogen by the action of dilated sulphuric acid and iron turnings, consists of two batteries of 40 casks, each producing at one operation lasting 3 hours, 5,375 cubic ft. of hydrogen, and working alternately.

At the trial trip three days were required to fill the balloon. It was ready on the 1st of February, in the evening, and it was kept inflated all night, but at two in the morning it was allowed to ascend sufficiently to attach the car, rudder, fan, connections, etc. The loss of gas during the night had been inappreciable, and previous experiments showed that the varnished silk was perfectly reliable. The wind had risen and the meteorological bulletins were far from being encouraging. However, the inventor decided to make the ascent, and after having repaired a slight damage, he left the ground at 1 P. M.

There were about two-thirds of a ton of ballast on board, and the balloon was in perfect equilibrium; 350 lbs. of ballast were thrown out, and the ascending force thus produced carried the balloon up rapidly.

A strong wind was blowing from the south. A few minutes after the departure, the shaft of the screw was lowered upon its bearing, and was started by the eight men together, slowly at first, and then with an increased speed. The rudder was first moved to the right, then to the left, and then was adjusted in order to ascertain how far its influence would be felt by the balloon. When the screw was set in motion, the effect of the rudder was immediately felt, as desired, proving that the balloon had acquired a sufficient speed with relation to the surrounding air.

The experimental trips had a threefold purpose: to ascertain the stability of the balloon, the relative speed that could be obtained, and the manner in which it obeyed the rudder, either on a fixed course or in tacking. An anemometer previously regulated gave the relative speed of the balloon; a compass attached to the car indicated the direction of movement. To measure the course followed in relation to the ground, a planchette was fixed to the side of the compass parallel to the vertical plane, and in the direction of the true north. The field of the planchette was painted black, the part forming a vertical surface being white. By this arrangement it was very easy to obtain a visual ray in a vertical plane, the verticality of the planchette being assured by the mode in which the compass was hung. By observing any clearly defined object on the ground, passing beneath the observer, and then by turning the planchette in the direction of the same object, when it was shifted from the vertical plane, the direction of the route followed by the balloon could be read direct off the compass.

The same observation gives the speed of the balloon, the height being observed by a barometer.

Between 1.15 P. M. and 2.35 P. M. eight observations were taken of the height of the balloon, of the temperature of the route measured on the ground in relation to the magnetic meridian, four times with the screw not working, and four times whilst it was being driven by eight men. At 2.35 P. M. it was resolved to descend, and at 3 P. M. the balloon touched ground at Mondécourt, exactly at the village indicated on the map of the route laid out beforehand from the calculated deductions of direction and of speed.

The landing was effected with perfect success and without accident, in spite of the force of the wind. M. Dupuy de Lome arrives at the following conclusions from the results of the trial: That the stability of the balloon was perfect, that it manifested no signs of oscillation under the action of the eight men working the screw, and that the shifting of the weight in the car produced no sensible movement. The vertical axis was only shifted—under the most trying conditions—a small part of a degree, and longitudinally there was no change.

In comparing the direction of the balloon drifting freely before the wind, with the direction given to it when the screw was in operation, it was found that the resultant made with the normal direction an angle of 12 deg. It is stated also that the speed given to the balloon, with 27½ revolutions of the screw was 6½ miles an hour, whilst the rate due to the wind alone was from 26 to 37 miles an hour.

With the same weight for a mechanical motor as that required by the eight men for driving the screw, a force ten times as great might have been obtained, and the speed due to the balloon under such improved conditions would be 13.60 miles per hour. With such a power it would apparently be practicable not only to make a considerable angle with the wind's direction, but also under favorable circumstances to shape the course of the balloon according to will.

ON THE THEORY OF THE STEAM ENGINE.*

UNITS OF MEASUREMENT.—PHYSICAL PROPERTIES OF STEAM.

1. From the principle that heat and work are mutually convertible, it follows that quantities of heat may be expressed in foot pounds, and conversely, that quantities of work may be expressed in thermal units. In thermo-mechanical questions it is necessary to have a common unit of measurement for heat and work, and in Rankine's work the foot pound has been adopted, but the thermal unit might likewise have been adopted, in which case quantities of work would be expressed in thermal units by dividing by 772: thus, 1-horse power is represented by $\frac{33000}{772}$ or 42.75 thermal units per minute. This mode of measurement possesses the advantage of leading to smaller numbers than the other; but, nevertheless, it will be seen herafter that the foot pound is the most convenient unit.

In measuring temperature we employ Fahrenheit's scale as the one in common use, although the centigrade scale is far more convenient, and it is to be hoped may ultimately be adopted.

2. The density of a vapor or gas is best measured by the volume which 1 lb. of it occupies, for which the convenient term "specific volume" is used by Zeuner. In the case of saturated steam the specific volume is given by the approximate formula $p v^{1\frac{1}{16}} = \text{constant}$, up to a pressure of 120 lbs. per sq. in. (Rankine, p. 403.) The elaborate calculations of Zeuner have fully confirmed this formula as representing with accuracy the density of steam as calculated from the relation existing between its latent heat of evaporation, temperature, and specific volume. According to him, the agreement (from .5 to 14 atmospheres) is almost exact, if the index 1.0646 be used in place of Rankine's index $\frac{17}{16} = 1.0625$. (Mechanische Warme Theorie, p. 294.) The value of the constant is about 475, if the pressures be in pounds per sq. in., and the volumes in cubic ft. If we employ Zeuner's index, the formula, when adapted to logarithmic computation, becomes

$$\log v = 2.516 - .939 \log p.$$

On account of the difficulty of obtaining steam in a perfectly dry and saturated condition, the density of steam can hardly be said to have been determined experimentally in a thoroughly satisfactory manner. The best experiments are those made by Fairbairn and Tate, who have given the following formula to represent them:—

$$v = .41 + \frac{389}{p - .35}$$

where v is the specific volume in cubic feet, and p is the pressure in lbs. per sq. in. This formula is very convenient in calculation, but can only be used for pressures between about 20 and 60 lbs. per sq. in. (absolute); below 20 its results are much too large, above 60 they are much too small. (Comp. Art. 24.)

The density of steam is likewise frequently measured by its "relative volume," that is, by the ratio which its volume bears to the volume of the water from which it was produced. To obtain the relative volume we have simply to multiply the specific volume by 62.5.

The complex relation between the temperature and pressure of saturated steam can only be expressed for a wide range of pressure by formulæ, such as that given by Rankine (p. 237), which require very tedious calculations. For pressures between 6 and 60 lbs. per sq. in. we may use the formula

$$p = \left(\frac{t + 40}{147}\right)^5$$

where p is the pressure in lbs. per sq. in., and t is the temperature Fahrenheit. From 60 to 120 lbs. per sq. in. this formula may likewise be used, but unity should then be added to the result.

Rankine has given a table of the pressure corresponding to a given temperature, but the table unfortunately only extends to every 9 deg. F. For the convenience of students a table is subjoined of the temperature corresponding to a given pressure for every pound on the sq. in., from 1 to 120. Fuller tables in English measures, which appear accurate so far as the writer has been able to examine them, will be found in "Porter on the Richards

* Notes of the Theory of the Steam Engine, being part of a course of instruction, in the subject given in the Royal School of Naval Architecture and Marine Engineering by James H. Cotterill. London, E. & F. N. Spon.

Indicator." The diagram recently published by Rankine is likewise convenient for obtaining the pressure and specific volume corresponding to a given temperature.

Table of the Temperature of Saturated Steam Corresponding to a Given Pressure.

P.	$t°$.	P.	$t°$.	P.	$t°$.
1	102	41	269	81	313
2	126	42	270	82	314
3	142	43	272	83	315
4	153	44	273	84	315
5	162	45	275	85	316
6	170	46	276	86	317
7	177	47	277	87	318
8	183	48	278	88	319
9	188	49	280	89	319
10	193	50	281	90	320
11	198	51	282	91	321
12	202	52	284	92	322
13	206	53	285	93	323
14	210	54	286	94	323
15	213	55	287	95	324
16	216	56	288	96	325
17	220	57	289	97	326
18	223	58	291	98	326
19	225	59	292	99	327
20	228	60	293	100	328
21	230	61	294	101	329
22	233	62	295	102	329
23	236	63	296	103	330
24	238	64	297	104	331
25	240	65	298	105	331
26	242	66	299	106	332
27	244	67	300	107	333
28	246	68	301	108	333
29	248	69	302	109	334
30	250	70	303	110	335
31	252	71	304	111	335
32	254	72	305	112	336
33	256	73	306	113	337
34	258	74	307	114	337
35	259	75	308	115	338
36	261	76	309	116	339
37	263	77	309	117	339
38	264	78	310	118	340
39	266	79	311	119	341
40	267	80	312	120	341

3. The specific heat of water increases slowly with the temperature, as is shown by the formula (1), page 246. It is usually supposed unity, but at high temperatures the error in doing so is not inconsiderable ; thus, at a temperature of 400 deg. F., corresponding to a pressure of 250 lbs. per sq. in., the specific heat of water is 1.04 ; and at a temperature of 300 deg., corresponding to 67 lbs. per sq. in., it is 1.02. Where accuracy is required, it therefore cannot be assumed unity at high pressures.

4. The total heat of evaporation of water from 32 deg. at t deg. is given by the formula.

$$\text{Total heat} = 1091.7 + .305\ (T° - 32°)\ \text{(thermal units.)}$$
$$= 1082 + .305\ T°$$
$$\text{or} \qquad H = 835{,}300 + 235.46\ T°\ \text{(in foot pounds).}$$

which formulæ represent with accuracy the results of Regnault's experiments.

The formula commonly used for the latent heat of evaporation, namely,

$$l = 966 - .7\ (T° + 212)\ \text{(in thermal units)}$$

assumes that the specific heat of water is unity at all temperatures. If great accuracy is required at high pressures, Rankine's tables should be used, the interpolation in which, for temperatures intermediate to those given in the table, in this case presents no difficulty.

It will be seen hereafter that the quantity of heat necessary to produce 1 lb. of steam from 1 lb. of water depends upon the way in which the steam is produced ; it must, therefore, always be carefully remembered that the terms, "total heat of evaporation," "latent heat of evaporation," are conventionally restricted to the case where the steam is formed under *constant pressure.*

5. The external work done in turning 1 lb. of water, at a given temperature, into saturated steam at the same temperature, is $p\ (v - s)$ foot pounds, where v is the volume of steam produced in cubic ft., p the pressure in lbs. per sq. ft., and s the volume of 1 lb. of water or .016 cubic ft. In practice, s is usually neglected, the error so produced being only .8 per cent. at pressure of 226 lbs. per sq. in., and much less at lower pressures. When necessary, it is easy to take into account by subtracting .016 from the given value of v.

The calculation of pv, especially for pressures intermediate between those given in Rankine's tables, is troublesome, and hence a shorter method is desirable. If saturated steam conformed to the perfectly gaseous laws, pv would be given by a formula of the form

$$p\,v = a\ (461 + t)$$

where a is a constant.

On trial, however, it appears that, except at very low pressures, the errors of this formula are too great to render it of practical use: and if we modify it, writing

$$p\,v = A + B\,t$$

where A and B are two constants determined by trial, the same is true at tem-

peratures above 212 deg. Zeuner, however, proposes the formula

$$\text{External work} = p\,(v-s) = A + B\,t - h$$

where A and B are constants determined by trial, and h is the heat (in foot lbs.) required to raise the temperature of 1 lb. of water from 32 deg. to t deg., a quantity given in Rankine's tables in the column headed h. If the specific heat of water, were unity at all temperatures, this formula would be of the same form as the last, h being 772 (t deg.—32 deg.); in fact, however, h increases more rapidly than this, and his quicker increase appears on trial very approximately to balance the errors of the original formula.

If we take A=15,450 (a value somewhat less than that which coresponds to Zeuner's value) and B=846, the formula becomes

$$\text{External work} = 15{,}450 + 846\,t - h$$

which, as far as the writer has been able to examine it, agrees well with the results derived from Rankine's tables. This formula is very convenient in calculation, as the value of h is readily interpolated for temperatures intermediate to those given in the table. For temperatures below 212 deg. we may write for h, its approximate value 772 (t–32), and thus obtain

$$\text{External work} = 74\,(542 + t).$$

A still more convenient formula is derived from the formula given in Art. 2 for the density of steam. Supposing the pressure given in pounds per sq. in., and the product pv in foot pounds, we have

$$\text{Log}\,(p\,v) = 4.675 + .061 \cdot \log p.$$

The results derived from this formula are sufficiently accurate at all ordinary pressures.

CYCLE OF OPERATIONS.—INTERNAL WORK.

6. The principle of the "cycle of operations" is usually stated in the following form. Let a substance change its temperature and volume (or more generally its molecular condition) from some given state, and, passing through a complete cycle of such states, return to its original state; then the difference between the whole heat absorbed by the substance in one part of the process, and the whole heat rejected by the substance in another part of the process, is equal to the external work done by the body during the process. For example, let a pound of water be forced into a boiler, there evaporated, then pass through the engine into the condenser, and finally, after rejecting heat into the injection water, become once more water of the same temperature as before; then the difference between the heat absorbed in the boiler and rejected in the condenser by that pound of water, is equal to the effective work done by the engine per pound of steam.

This is a primary axiom of the mechanical theory of heat, evidently true on the supposition of the convertibility of heat and work, because no other effect has been produced, except the external work, the substance being in the same state as before by hypothesis. Its application, however, is easier when it is put in a different and somewhat more simple form. Let the substance change from a state A to a state B, and let Q_1 be the heat expended, U_1 the external work done during the change; let it now change back from B to A by a different set of changes, and let the heat rejected by the substance be Q_2, and the work done upon it by external bodies be U_2, then, by what has been stated above,

$$Q_1 - Q_2 = U_1 - U_2$$

but Q_2 and U_2 are exactly the heat which would have been expended, and the work which would have been done if the substance had changed from A to B by the *second route reversed;* hence, writing the equation in the form

$$Q_1 - U_1 = Q_2 - U_2$$

we see that the principle may be put in the form—

If, from the whole heat requisite to produce a given change of state, the equivalent of the external work be subtracted, then the remainder is always the same in whatsoever way the change is produced.

This form of the principle is in Rankine's work (see p. 304) deduced as a corollary from a different proposition, but it appears to be a necessary conclusion from the original form of the principle (at least whenever some way exists of passing from the state A to the state B, which is capable of being reversed), and it is, in fact, so assumed explicitly or implicitly by other writers. Indeed, it may not be questioned whether this form of the principle has not as much claim to be considered axiomatic as the other.

To take an example: Water at a tem-

perature of 32 deg. requires about 904,000 foot pounds of heat to raise its temperature to 293 deg. F and to evaporate it at that temperature, which corresponds to a pressure of 60.4 lbs. per sq. in., or about 8,700 lbs. per sq. ft. Its volume is then very nearly 7 cubic feet, and the external work done very approximately 60,900 foot lbs. Subtracting this from 904,000 foot lbs. we get as a remainder 843,100 foot lbs. But now let us suppose that we produce our steam without doing external work. This may be very easily done; we have only to place our pound of water at 32 deg. in a close vessel, the capacity of which is 7 cubic ft., and apply heat till all the water is evaporated; we shall then have a pound of saturated steam at the temperature of 293 deg. F. as before, but we shall have done no external work, and the heat expended is therefore no longer 904,000 foot lbs., but 843,100 foot lbs.

We have, in fact, in the second case produced the steam and the steam only, while in the first case we have not only produced the steam, but we have also produced 60,900 foot lbs. of mechanical work, and the whole heat expended is separable into the two parts necessary to produce each effect separately.

So it is in the most general case; we must always separate the external and visible work done on external bodies from the internal and invisible work done in changing the state of the body. The second part, which we shall call the internal work, is always the same, however the change is produced.*

In some important cases the body is in motion, and in this case, in applying the principle, any change of kinetic energy must be taken into account. (Comp. Art. 36.)

The authorities on thermo-dynamics do not place the principle considered in this article in the same rank as the principle of the convertibility of heat and work, which is the first principle of the mechanical theory of heat, and the "second principle," which we shall have to consider hereafter. The reason of this apparently is, that it partakes rather of the nature of an axiom than of an experimental law. It is nevertheless admitted by all writers, and the conception by Carnot of a cycle of operations was the first step to a true theory of heat engines.

7. If we separate, in the manner just explained, the latent heat of evaporation of water into two parts, the internal work and the external work, and if we assume for the external work the formula given in 5, namely:

$$\text{External work} = 15{,}450 + 846\,t - h$$

we shall obtain a very simple formula for the internal work, for evidently

$$\begin{aligned}\text{Internal work} &= \text{Latent heat} - \text{external work}\\ &= \text{Latent heat} + h - 15{,}450 - 846\,t\\ &= H - 15{,}450 - 846\,t.\end{aligned}$$

This internal work may also be called the internal latent heat of evaporation, and, if the term latent heat had been invented after the discovery of the mechanical theory of heat, might very probably have been called simply the latent heat. If we denote it by ρ, then replacing H by its value,

$$\begin{aligned}\rho &= 819{,}850 - 611\,t \quad \text{(foot pounds)}\\ &= 1{,}062 - .79\,t \quad \text{(thermal units)}.\end{aligned}$$

PRESSURE EQUIVALENT TO THE EXPENDITURE OF HEAT—ENGINE WORKING WITH DRY SATURATED STEAM.

8. If A be the area of a piston, κ the space through which it moves, and p the pressure upon it, then $p\,A\,\kappa$ is the work done. Let now $A\,\kappa = 1$, that is, let the piston sweep through 1 cubic foot, then the work is simply p, the pressure supposed expressed in lbs. per sq. ft. Thus the pressure on a piston in lbs. per sq. ft. may also be considered as the work done per cubic foot swept through by the piston. But we can easily find the heat expended by an engine per cubic foot swept through by the piston, and when expressed in foot pounds, it follows that it may be regarded as a "pressure equivalent to the expenditure of heat," and by division by 144, it may be expressed in lbs. per sq. in.

This mode of expressing the expenditure of heat in an engine, was introduced by Rankine, and is far more convenient

* The expression "internal work" has been hitherto more often used in a different sense; the remainder spoken of in the enunciation is separated into two parts, one of which is described as the heat necessary to produce change of temperature, and the other as the heat necessary to produce change of molecular position, for which second part the term "internal work" has been appropriated. (See, for instance, Tait's "Thermo-dynamics," Art. 46.) But this distinction does not appear to us a useful one, at least at the outset of the subject; the student is thereby compelled to form some hypothesis as to the constitution of matter, whereas "internal work," as defined in the text, is evidently capable of exact definition without any hypothesis at all. We have, therefore, followed Zeuner in his use of the word without entering (as Zeuner does) on the above distinction.

than any other; for once knowing the pressure equivalent to the expenditure of heat, we obtain the actual expenditure of heat in exactly the same way as we obtain the power of the engine from the mean effective pressure; and, for this reason, the foot pound is a more convenient unit of measurement in the theory of the steam engine than the thermal unit.

In a non-expansive engine, working with dry saturated steam, the pressure equivalent to the expenditure of heat is easily found as follows:

Let H be the total heat of evaporation of water *from* the temperature of the feed-water *at* the temperature of the boiler, v_1 be the specific volume of the boiler steam, then H_1 is the heat expended for every pound of steam, and consequently $\frac{H_1}{v_1}$ for every cubic foot of steam admitted into the cylinder; but for every cubic foot of steam admitted, the piston sweeps through one cubic foot, hence it follows that where p_h is the pressure required.

$$p_h = \frac{H}{v_1} \text{ (lbs. per sq. ft.)}$$

9. If from the heat expended in an engine we subtract the work done, we get the heat rejected, and hence if p_r be the pressure equivalent to the heat rejected,

$$p_r = p_h - (p_1 - p_2) = \frac{H_1}{v_1} - (p_1 - p_2)$$

in the case of the non-expansive engine, p_2 being supposed the back pressure.

10. Let us now take the case of an expansive engine working with dry saturated steam, and find the pressure (p_h) equivalent to the expenditure of heat. This may be done in two ways, both involving essentially the same principle.

First Method.—Let the pressure be at admission p_1, at the end of the expansion p_2 and let the corresponding specific volumes be v_1 v_2; then at the end of the stroke we have by hypothesis a cylinder full of dry saturated steam of the pressure p_2, which at exhaust rushes into the condenser (or atmosphere), and is there condensed. Let us now imagine a non-expansive engine working *at pressure* p_2, with the same back pressure p_2; at the end of *its* stroke we shall have a cylinder full of dry saturated steam, which at exhaust will rush into the condenser (or atmosphere), and there be condensed. And *since the circumstances of the condensation are the same*, the heat rejected will be the same in the two cases, that is,

$$p_r = \frac{H_2}{v_2} - (p_2 - p_2)$$

where H_2 is the total heat of evaporation *from* the temperature of the feed-water *at* the temperature corresponding to p_2, the final pressure.

Let now $p_m - p_2$ be the mean effective pressure, then the work done by the engine for every cubic foot swept through by the piston is $p_m - p_2$ and hence, since

Heat expended = heat rejected + work done.

$$p_h = p_r + p_m - p_2 = \frac{H_2}{v_2} + p_m - p_2.$$

Second Method.—But we can also reason thus:

Each pound of the steam at the end of the stroke is dry saturated steam of pressure p. However that steam is produced, we must always have

Heat expended=Internal work+External work,

of which two terms the Internal work is always the same, while the External work is the energy exerted by the steam on external bodies during its formation. Now if that steam be formed by the ordinary process of evaporation at constant pressure p_2, then the heat expended will be H_2 the total heat of evaporation *from* the temperature of the feed-water *at* the temperature of evaporation, and we have, therefore, for every pound of steam,

$$\text{Internal work} = H_2 - p_2 v_2$$

but the steam is actually formed by a complex series of changes, such that, instead of overcoming the uniform pressure p_2, it presses on the piston with mean pres- p_m, and exerts on that piston for every poundof steam the energy $p_m v_2$.

$$\therefore \text{ Heat expended} = H_2 - p_2 v_2 + p_m v_2 \text{ (per lb.)}$$

and the heat per cubic foot swept through by the piston is given by

$$p_h = \frac{H_2}{v^2} + p_m - p_2 \text{ (as before).}$$

The reader should notice that the energy exerted by each pound of steam, namely $p_m v_2$, may be separated into two parts, of which one $(p_m - p_h)v_2$ is employed in overcoming external resistance, and the other $p_2 v_2$ is expended in work done upon the condensing steam, and reappears in the form of heat in the condenser.

11. The engine being supposed working

with dry saturated steam, the equation to the expansion curve is $pv^{\frac{17}{16}}$=constant, from which, if the ratio of expansion be given, the final pressure p_2, and the mean forward pressure p, are readily determined.

It will not, however, be possible that the steam should be dry and saturated during the expansion, unless heat be supplied by means of a steam or hot-air jacket while the expansion is going on. For suppose the boiler to supply dry saturated steam, then the heat required to produce it will be represented by

$$p'_h = \frac{H_1}{v_2}$$

for H_1, the total heat of evaporation *from* the temperature of the feed-water *at* the temperature of the boiler, is the heat expended in the boiler per lb. of steam, and therefore $\frac{H_1}{v^2}$ is the heat expended in the boiler per cubic foot swept through by the piston, or p'_h is the pressure equivalent to the heat expended in the boiler. But p_r is greater than p'_h, for

$$p_h = \frac{H_2}{v_2} + p_m - p_2$$

$$\therefore p_h - p'_h = \frac{H_2 - H_1}{v_2} + p_m - p_2$$

$$= p_m - p_2 - \frac{235\,(t_1 - t_2)}{v_2}$$

and it will be found on trial that the expression on the right hand side is always positive. Evidently $p_h - p'_h$ represents an amount of heat which must be supplied to the steam elsewhere than in the boiler, and if this be not done, the steam cannot be dry at the end of the stroke, but condensation must take place.

When a steam or hot-air jacket exists, moist steam absorbs heat with great rapidity from the hot sides of the cylinder, and experience appears to show that the steam is really prevented from condensing in this way. On the other hand, when the steam is once dry it absorbs heat very much more slowly, and there is consequently good foundation for the supposision that, when the cylinder is jacketed, the steam is dry and saturated during the expansion. But when the cylinder is not jacketed and the steam is not superheated before it enters the cylinder, then condensation necessarily takes place, even though the cylinder be so well clothed that there is no sensible radiation from its external surface.

The heat produced by friction of the cylinder no doubt modifies this statement to a certain extent. The amount of piston friction is variable and uncertain, but we suppose it much overestimated in normal circumstances, if we take it as 1 lb. per sq. in.; this 1 lb. per sq. in. diminishes the pressure equivalent to the expenditure of heat by the same amount, but such diminution is not sufficiently sensible to reduce the condensation.

Nevertheless the reader must bear in mind that this conclusion is based solely on numerical calculations from the formula just given, and if a different fluid than water were used might not be true. For example, in the case of ether, it is believed that super-heating, and not condensation, would take place.

12. The formula just now given for the pressure equivalent to the expenditure of heat

$$p_h = \frac{H_2}{v_2} + p_m - p_2$$

is true whether or not the steam is dry and saturated at other times, provided only that it is so at the end of the stroke. With this restriction the treatment of the steam may be anything we please; it may contain suspended water, or it may be superheated, the formula will still be true. The value of p_m of course will be different in each case, but when p_m is known from an indicator diagram or otherwise, p_h can always be determined, We shall consider this further hereafter.

13. By use of the formula given in 5 for pv

$$p\,v = 15{,}450 + 846\,t - h$$

we can put the formula for p_h in a form in which the calculations from it are very simple. For

$$p_h = \frac{H_2}{v_2} + p_m - p_2$$

$$= p_m + p_2\left(\frac{H_2}{p_2\,v_2} - 1\right).$$

Now let t_1 be the temperature of the feed-water, then

$$H_2 = 772\,(1082 + .305\,t_2) - 772\,(t_1 - 32)$$

Also, since t_2 is never a high temperature, we may put very approximately

$$h = 772\,(t_2 - 32).$$

Therefore we have

$$\frac{p_2 v_2}{772} = \frac{15{,}450 + 846\, t_2}{772} - (t_2 - 32)$$

$$= 52 + .096\, t_2.$$

$$\therefore \frac{H_2}{p_2 v_2} = \frac{1{,}114 + .3\, t_2 - t_4}{52 + .096\, t_2}$$

$$\therefore p_h = p_m \frac{1{,}062 + .21\, t_2 - t_4}{52 + .096\, t_2}\, p.$$

The formulæ given by Rankine are

$p_h = p_m + 15\, p_2$ (for condensing engines)

$p_h = p_m + 14\, p_2$ (for non-condensing engines)

agreeing well with the results of the foregoing more general formula. These formulæ are very simple and convenient in calculation, as p_m and p_2 do not require to be expressed in pounds per square foot, as they must be in the orginal form of the formula.

It is, however, necessary to know p_2 with great accuracy, any error being multiplied by 15 or thereabouts produces an error in p_h some 15 times as great as an equal error in p_m.

THERMO-MECHANICAL PROPERTIES OF THE PERMANENT GASES.

14. If $p\ v\ p^1\ v^1$ be the pressure and specific volume of air at two temperatures $t\ t^1$, measured by Fahrenheit's scale *on the air thermometer*, it is known that very approximately

$$\frac{p\, v}{p^1 v^1} = \frac{461 + t}{461 + t^1} *$$

It is likewise known that this relation is very approximately true of all other permanent gases, that is, gases which have not yet been liquefied by application of cold and pressure; while, on the other hand, it is less approximately true of gases which are capable of liquefaction, such as carbonic acid. Thus, it is easy to conceive an ideal gas for which this relation is mathematically correct, which ideal gas may be considered as a perfect gas, just as from the properties of water we conceive a perfect fluid, although, in fact, no such thing actually exists.

The above equation represents, then, a relation always existing between the pressure volume and temperature of a perfect gas. It may be written in the form

$$p\, v = \frac{p^1\, v^1}{461 + t^1}\,(461 + t)$$

or

$$p\, v = c\, T$$

where c is a constant which for air has the value 53.15, and T is the† temperature measured by Fahrenheit's scale on a perfect gas thermometer, from a zero 461 deg. below the zero of Fahrenheit's scale, or 493 deg. below the freezing point of water. Evidently the value of c will be proportional to the density of the gas at some given pressure and temperature.

Again, if air be heated at constant pressure through 1 deg. F. measured on the air thermometer, it is found that the quantity of heat absorbed by each pound of the air is very approximately .2375 thermal units, or 183.35 ft. lbs., whatever be the pressure or temperature of the gas; in other words, its specific heat at constant pressure when measured in foot pounds is always 183.35. So also it is found that the specific heats at constant pressure of the other permanent gases are always the same, and are, moreover, proportional to their densities, that is, proportional to c very approximately. We are thus led to conclude that these laws are characteristic of the perfectly gaseous state.

Lastly, it is known that the same laws hold good with respect to the specific heat at constant volume of air, and that the ratio of the specific heat at constant pressure to the specific heat at constant volume is 1.408, so that the actual value of the specific heat at constant volume is $\frac{183.35}{1.408} = 130.2$. It is true that at present the difficulties of experimenting directly on the specific heat at constant volume of gases have not been overcome, and that the experiments on the ratio of specific heats give discordant results; but for our present purpose there seems no impropriety in assuming the known result, as it will be seen presently we have two independent means of testing the truth of the supposition.

We now observe that the difference of the two specific heats of air is 53.15, that is, it is equal to c; further, as just stated, the specific heat at constant pressure of all permanent gases is proportional to c. We are hence led to the conclusion that, if K, K_1 be the specific heats (expressed in foot pounds) of a perfect gas at con-

* The numbers given may probably require slight alterations not exceeding 1-200th part, but the certainty and importance of the alterations are not sufficient to render it necessary to depart from the values as given by Rankine.

† By absolute temperature we mean at present simply temperature measured in this way.

stant pressure and constant volume respectively, we must always have

$$K_p - K_v = c$$

as a mathematically exact relation satisfied very approximately by the actual permanent gases.

15. We can now obtain a very important result, namely, that the heat expended in internal work, when any change of state is produced in a perfect gas, is simply $K_v (t_1 - t_2)$ where t_2 t_1 are the temperatures at the beginning and end of the change.

For let p_2 v_2 p_1 v_1 be the corresponding pressures and volumes of the gas: and let us by application of heat change the volume of our gas from v_2 to v_1, the pressure remaining constantly p_2, then by definition

$$\text{Heat expended} = K\ (t - t_2)$$

where t is the new temperature. Also

$$\text{External work done} = p_2\ (v_1 - v_2)$$
$$= c\ (t - t_2)$$
$$\therefore \text{Internal work} = (K_p - c)\ (t - t_2$$
$$= K_v\ (t - t_2.$$

Next let the pressure be changed from p_2 to p_1 at the constant volume v_1 attained by the first operation; then by definition,

$$\text{Heat expended} = K_v\ (t_1 - t)$$

and in this case no external work is done, and

$$\therefore \text{Internal work} = K_v\ (t_1 - t)$$

Add together the two values of the internal work, and we get $K_v (t_1 - t_2)$ as the internal work done in changing from the original state to the final state.

But this internal work, by the principle of Art. 6, is the same in every case, hence the proposition is true.

Let us now test the truth of this result by the following experiment:—

Air is contained in a vessel which communicates by a pipe furnished with a stop-cock with another vessel, in which a very perfect vacuum exists, or else which contains air of exactly the same temperature but of a different pressure. The stop-cock being opened, air rushes from one vessel to another; after a time the motion ceases, and the temperature is found to be very slightly altered.

This experimental result confirms the truth of what has been stated, for in passing from one vessel to the other no heat is expended on the air, and no external work is done, therefore the change of internal work must be zero; that is, if our proposition is true, the temperature is unaltered.

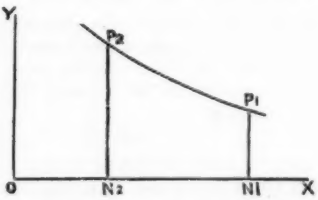
When non-permanent gases are experimented on, the temperature is found to be sensibly changed.

In our mode of statement this experimental result is the first confirmation of the value assumed for the specific heat of air, at constant volume. Indeed, it is possible hence to prove, by reasoning analogous to that given above, that the specific heat, at constant volume of air, must have the value assumed by us and no other.

16. We can now find the heat expended in producing any change in a pound of air, for

$$\text{Heat expended} = \text{internal work} + \text{external work}$$
$$= K_v\ (t_1 - t) + \text{external work}$$
$$= K_v \cdot \frac{p_1 v_1 - p_2 v_2}{c} + \text{external work}$$

which is the general equation of the action of heat in a perfect gas. We may represent this geometrically thus: Drawing a diagram in which as usual ordinates represent pressures and abscissæ represent volumes; let P_2 N_2, O N_2 be the initial pressure and volume, P_1 N_1, O N_1 the final pressure and volume. Then the area P_2 P_1 N_1 N_2 represents the work done by the expansion of the gas, where P_1 P_1 the expansion curve is perfectly arbitrary, and may be anything we please, if heat be applied according to a proper law. The actual expenditure of heat is geometrically represented by



$$\frac{K_v}{c}(\text{rectangle } P_1 N_1 . ON_1 - \text{rectangle } P_2 N_2 . ON_2)$$
$$+ \text{area } P_2 P_1 N_1 N_2$$

There are two important cases—

First, let the expansion take place at constant temperature, we then have

$$\text{Heat expended} = \text{Area } P_1 N_1 N_2 P_2;$$

but the expansion curve is then a common hyperbola, the asymptotes of which are O X O Y. Then, the area

$$P_1 N_1 N_2 P_2 = P_1 N_1 . O N_1 \log \frac{O N_1}{O N_2}$$

the logarithm being hyperbolic,

$$\therefore \text{Heat expended} = p_1 v_1 . \log r = c\,T \log r$$

where r is the ratio of expansion and T is the absolute temperature.

Secondly, let the gas expand in a non-conducting non-radiating cylinder; that is, let it expand without gain or loss of heat, then the expansion curve is a curve called the adiabatic curve, the form of which we require to find. Evidently we have

$$\frac{K}{c}(p_2 v_2 - p_1 v_1) = \text{Area } P_1 N_1 N_2 P_2$$

By the aid of the differential calculus, we easily find that the curve possessing this geometrical property, is given by the equation

$$p v^\gamma = \text{constant}$$

where $\gamma = \frac{K_p}{K_v}$. This, then, is the equation of the adiabatic curve.

An interesting result has been arrived at by Zeuner, of which this is a particular case; it is easy to show that, if the pressure and volume change in such a way that the specific heat is a constant quantity κ, then they must satisfy the equation

$$p v^n = \text{constant.}$$

where $n = \frac{K - K_p}{K - K_v}$: the adiabatic curve is the special case in which $K = 0$.

From the form of the adiabatic curve is obtained a second experimental confirmation of the properties of the specific heat at constant volume assumed in 14; for it can be shown that very approximately the velocity of sound in a gas, when the adiabatic curve is of this form, must be

$$\sqrt{g \gamma c T}.$$

(Compare Rankine's Art. 252.)

When a gas expands without gain or loss of heat, its temperature falls. For suppose it expands from v_1 to v_2, and let its pressure and temperature then be p_1, T_1 and p_2, T_2, then we have

$$p_1 v_1 = c T_1 ; \; p_2 v_2 = c T_2 ; \; p_1 v_1^\gamma = p_2 v_2^\gamma.$$

$$\therefore c T_1 v_1^{\gamma-1} = c T_2 v_2^{\gamma-1}$$

or

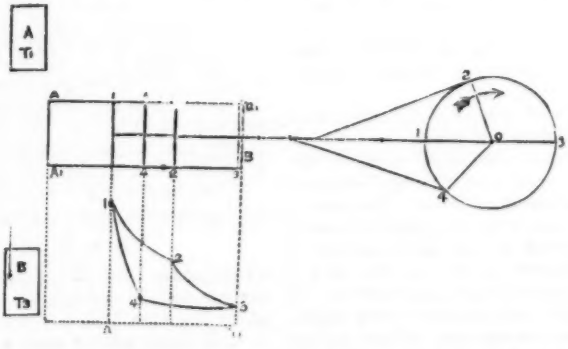
$$T_2 = T_1 . \left(\frac{1}{r}\right)^{\gamma-1}$$

where r is the ratio of expansion, a result which shows that the temperature falls, and enables us to find by how much it has fallen.

THEORY OF A HEAT ENGINE WORKING WITH A PERFECT GAS—CONDITIONS OF MAXIMUM EFFICIENCY.

17. The simplest kind of heat engine is constructed as follows:

A B is a working cylinder containing a given quantity, say 1 lb., of a perfect gas always included between the cylinder cover A A' and a piston, successive positions of which are represented in the figure by 11, 22, 33, 44, and which may be supposed connected in the usual way with a crank, corresponding positions of which are O_1 O_1, O_2 O_2. The right hand portion



of the cylinder between the cover B B' and the piston is empty.

A and B are two bodies capable of communicating or abstracting indefinite amounts of heat to any body placed in contact with them and of temperatures (absolute) T_1 and T_2 respectively.

Suppose the crank moving in the direc-

tion of the arrow, and initially let it be in the position O_1, and let the pressure volume and temperature of the gas be then p_1 v_1 T_1 respectively. Then, as the crank moves on, the volume of the gas increases, and if no heat were applied to it the temperature would fall; but this is prevented by placing the body A in contact with the cylinder, which is to be supposed a perfect conductor, so that the slightest depression of the temperature of the gas below T_1, causes heat to flow from A into the gas, and thus the temperature of the gas is maintained constantly at T_1. During this first operation, then, the gas expands at constant temperature, and the expansion curve 1, 2 in the indicator diagram above, is a common hyperbola.

The expansion having reached some convenient point 2, the body A is to be removed from the cylinder, so that no more heat is received by the gas; its temperature then falls, instead of remaining constant, and the expansion curve 2, 3 on the indicator diagram above, is now an adiabatic curve given by pv^γ=constant. This goes until the piston has reached the end of its stroke and begins to return to compress the air again, and raise its temperature according to the same law by which it fell during the expansion. But this rise of temperature is prevented by the application of the body B, the temperature of which is T_2, the temperature of the gas at the end of the stroke, and which abstracts heat from the gas the instant its temperature rises above T_2.

Thus the gas is compressed at constant temperature T_2, and the compression curve 3, 4 on the indicator diagram given on preceding page, is a common hyperbola.

This compression goes on till the piston reaches a point 4, the position of which will presently be determined when the body B is removed and the temperature of the gas allowed to rise. The gas is then compressed without gain or loss of heat, so that the compression curve 4, 1 on the indicator diagram given on the preceding page, is an adiabatic curve. If now the point 4 has been properly taken, the temperature of the gas at the end of the stroke will be T_1, and the gas having returned exactly to its initial state, the process may be repeated as many times as we please.

The required point 4 is easily found thus: let p_2 v_2 p_3 v_3 p_4 v_4 be the pressure and volume at the points 2, 3, 4, then since 1, 2, and 3, 4 are common hyperbolas

$$\frac{p_1}{p_2} = \frac{v_2}{v_1} \text{ and } \frac{p_3}{p_4} = \frac{v_4}{v_3}$$

and since 2, 3, and 4, 1 are adiabatic curves

$$\frac{p_3}{p_2} = \left(\frac{v_2}{v_3}\right)^\gamma \text{ and } \frac{p}{p_1} = \left(\frac{v_1}{v_4}\right)^\gamma$$

Hence multiplying all four equations together.

$$v_1\ v_3 = v_2\ v_4 \text{ or } \frac{v_2}{v_1} = \frac{v_3}{v_4}$$

or—*the ratio of expansion during the reception of heat must be equal to the ratio of compression during the rejection of heat*, or since we equally have

$$\frac{v_3}{v_2} = \frac{v_4}{v_1}$$

—*the ratio of adiabatic expansion must be equal to the ratio of adiabatic compression.* It is easily seen that each of these last ratios must be equal to $\left(\frac{T_1}{T_2}\right)^{\frac{1}{\gamma-1}}$, which determines their value when the temperatures T_1 T_2 of the bodies A and B are supposed given.

Let us now examine how much work is done by this engine, and at what expenditure of heat.

During the operation 1, 2 the gas is receiving heat from A, and the quantity of heat it receives according to the last article is

$$Q = c\,T_1 \log r$$

where r is the ratio of expansion. During the operation 2, 3 which completes the forward stroke, the gas receives no heat, therefore Q is the heat expended in the forward stroke. At the same time the energy exerted on the piston by the gas is represented by the area 1, 2, 3, n^1 n.

In the backward stroke the gas rejects the heat into B, and the heat so rejected is

$$R = c\,T_2 \log r$$

At the same time the piston compresses the gas and does work upon it represented by the area 1, 4, 3 n^1 n; the engine, in fact, is single-acting and a fly-wheel will be required to carry it through the whole backward stroke.

The difference between these areas, namely, the area of the indicator diagram 1, 2, 3, 4, represents as usual the work

done by the engine. We might calculate this area, but it is simpler to apply the principle of the cycle of operations, for since the gas returns exactly to its original pressure, volume, and temperature, we must have

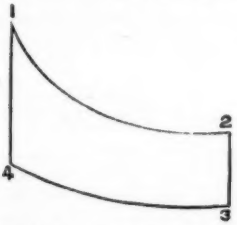
$$\text{Work done} = Q - R = c\,(T_1 - T_2)\log r.$$

The efficiency is now found from the consideration that the heat expended is Q,

$$\text{Efficiency} = \frac{\text{Work done}}{\text{Heat expended}} = \frac{T_1 - T_2}{T_1}$$

18. The simple heat engine just considered may be arranged to work in an indefinite number of other ways, one of which will now be considered as an example.

Let us suppose that the body A remains in contact with the cylinder throughout the forward stroke, and the body B throughout the backward stroke, the indicator diagram will now be as shown in the figure. 1 2 is an hyperbola as before, but now extends through the whole forward stroke, and 3 4 is also an hyperbola as before, but extending through the whole



backward stroke; but 1, 4, 2, and 3, are vertical straight lines representing the sudden rise of pressure on contact with the body A, and fall of pressure on contact with the body B, at the commencement of the forward and backward strokes respectively.

To find the efficiency of this arrangement we have, as before

$Q = c\,T_1 \log r$ = heat expended in forward stroke
$R = c\,T_2 \log r$ = heat rejected in backward stroke

and, as shown in 16, these quantities are also the works done upon the piston by the gas in the forward stroke, and upon the gas by the piston in the backward stroke,

$\therefore$ Work done by engine $= c\,(T_1 - T_2)$ log. r as before.

but the whole heat taken away from A, that is, the whole heat expended, is now no longer Q, because at the commencement of the stroke a quantity of heat $K_v(T_1 - T_2)$ has to be expended in raising the temperature of the gas from T_2 to T_1, and we consequently have

$$\text{Heat expended} = Q + K_v(T_1 - T_2) = c\,T_1 \log r + K_v(T_1 - T_2)$$

$$\text{Efficiency} = \frac{c\,(T_1 - T_2)\log r}{c\,T_1 \log r + K_v(T_1 - T_2)} = \frac{T_1 - T_2}{T_1} \cdot \frac{1}{1 + \dfrac{K_v}{c \log r} \cdot \dfrac{T_1 - T}{T_1}}$$

Thus we see that the efficiency of this arrangement is less than that of the other, and we likewise see why it is so, namely, because at certain points in the process the gas has its temperature raised and lowered by contact with the bodies A and B, that is, *that it receives and rejects heat at temperatures sensibly different from the temperatures of A and B.*

There are two conceivable ways of avoiding this loss of efficiency: the first is by storing up the heat rejected during the cooling represented by 2, 3, and employing it to produce the rise of temperature represented by 4, 1. This has been done in actual air engines by the contrivance called the regenerator. (See Rankine, Art 268.) The second is by inserting an auxiliary heat engine receiving heat from the hot gas of the original heat engine after it has finished its work in that engine; the work of this auxiliary engine will be so much additional work done without any additional expenditure of heat.

19. We shall now show that by no possible arrangement, with or without the additions just now mentioned, can we obtain an efficiency greater than that obtained by the original arrangement. We might do this by examining each particular case, but we prefer to reason more generally, as follows:—

Returning to the figure of Art. 17, and supposing initially the crank in the position O_1, let the engine turn in the opposite direction to that indicated by the arrow, neither A nor B being in contact, the gas will expand without gain or loss of heat, and the adiabatic curve 1, 4 will be described on the diagram. As soon as 4 is reached, let the body B be applied to prevent the temperature falling below T_1: heat is continually abstracted from B, the hyperbola 4, 3 is described on the dia-

gram. Now removing the body A, the piston returns, and the adiabatic curve 3, 2 is described; and, finally applying A to prevent the temperature rising above T_2, the hyperbola 2, 1 is described, heat all the while passing from the gas into A.

The whole process is now exactly the reverse of what it was; a heat R is abstracted from B, and a heat Q passes into A, while, instead of the engine doing work on external bodies, some force must be applied to the crank, which in each revolution will do the work Q—R. And thus, instead of heat passing from A to B, and during its passage a part of it being converted into mechanical energy, we have conversely, by application of mechanical energy, heat passing from B to A, and during its passage mechanical energy converted into heat. In short, the process is *reversible.*

Let us now imagine any other arrangement of this heat engine with or without the additions alluded to just now, and let heat expended be Q, the heat rejected R, and let $Q_1 - R_1 = Q - R$, that is, let the work done by this engine be equal to the work done by an engine of the original arrangement: and let us further suppose that this engine is employed to work the original engine backwards, a thing which we have just shown to be possible.

Now the efficiency of the one engine is $\frac{Q_1 - R_1}{Q_1}$ and of the other $\frac{Q - R}{Q}$; hence, if the first be greater than the second we must have Q_1 less than Q. This, however, is impossible, for the one engine takes away a heat Q_1 from A, and adds a heat R_1 to B, while the other engine takes away a heat R from B, and adds a heat Q to A; the combined action of the two then takes away $Q_1 - Q$ from A, and adds an equal quantity $R_1 - R$ to B. Thus, if Q_1 be less than Q, heat passes from B to A, and this effect is produced without any expenditure of work, for the combined engines require no power to work them. But this is absurd, for we may take it as an axiom that—*Heat cannot be made to pass from a cold body to a hot one without the expenditure of mechanical energy.**

It will now be asked why we cannot work this combined engine in a reverse direction and thus show that the efficiency of all possible arrangements must be the same. The answer to this question is, that it is the original arrangement only which admits of being reversed, for in all the other arrangements heat passes from the bodies to the gas, or reversely, at temperatures differing sensibly from that of the bodies themselves, and this is a process which is incapable of being reversed.

For example, suppose the arrangement of Art. 18 worked backwards, instead of the heat $c\,T_2 \log r + K_2 (T_1 - T_2)$ being taken away from B, and the heat $c\,T_1 \log r + K_1 (T_1 - T_2)$ being added to A, as would be the case if the process were exactly reversible, it will be found that the heat taken away from B will be $c\,T_2 \log r - K_2 (T_1 - T)$, and the heat added to A will be $c\,T_1 \log r - K_1 (T_1 - T_2)$; thus, the process not being reversible, the reasoning fails.

Since, then, no arrangement, even with the addition of a regenerator or auxiliary heat engine, can have a greater efficiency than the original, it follows that without these additions the efficiency must be less, and we finally arrive at the following important conclusions with respect to this kind of engine:

First.—The maximum efficiency is $\frac{T_1 - T_2}{T_1}$ where T_1 T are the absolute temperatures of the bodies A and B.

Secondly.—The conditions of maximum efficiency of the simple engine are, that the gas shall receive heat at the constant temperature of the body A, and shall reject heat at the constant temperature of the body B. Or, to express the same thing differently, that the process should be *reversible.*

The reader who has followed us so far, will now, without much difficulty, be able to proceed further, and to perceive that our reasoning is of much wider application; while, on the other hand, some help is obtained in comprehending what has gone before by the more general considerations to which we now proceed.

SECOND PRINCIPLE OF THE MECHANICAL THEORY OF HEAT.—ABSOLUTE TEMPERATURE.

20. To produce mechanical power by means of heat, it is in the first place necessary that we should have bodies of different temperatures, for it is evident that if all bodies were of the same tem-

*Some writers prefer a different form of this axiom. (See Tait's "Thermo-Dynamics," Art. 53.

perature, we could no more produce any change by means of heat than we could do work by the action of gravity if all bodies were on the same level. Mechanical energy, then, is produced from heat by the transfer of heat from a hot body to a cold one, and the power of turning heat into work must depend in some manner on the difference of temperature between the hot body and the cold one.

This alone, however, is not sufficient, for if heat simply pass from a body A to a body B, without the intervention of a third body, not only is no mechanical work done, but all the power of turning heat into work due to the difference of temperature of A and B is permanently lost, because the heat is now in the body B and cannot be made to pass back to A.

If, however, we take a third body capable of changing its volume by application of heat, and cause it to receive heat from the hot body and reject heat into the cold body, so that heat is transferred from the hot body to the cold one by its agency, we are then able by means of the changes of volume of this intermediate body to convert a portion of the heat into mechanical energy. It is, however, easy to see that only a portion can be so converted, for it will be found on reflection that rejection of heat into a cold body is just as indispensable a part of the process as reception of heat from the hot body, and thus a part of the heat necessarily merely passes through the intermediate body without being converted into mechanical energy. Thus, in the steam engine, the hot body is the hot gas in the furnace, the cold body is the atmosphere or condenser, the intermediate body is water, and the condensation of the steam after it has done its work is just as necessary a condition that work should be done as the evaporation of the water in the boiler.

Thus, for the production of mechanical energy from heat, we must have a hot body, by a cold body, and an intermediate body, by the agency of which heat is transferred from the hot body to the cold one.

And since the power of turning heat into work is wasted whenever heat passes from a hot body to a cold one without the agency of an intermediate body, it follows that the process of transformation will be most efficient when the intermediate body has the same temperature as the hot body when receiving heat, and the same temperature as the cold body when rejecting heat. Let us, for instance, suppose that the intermediate body rejects heat at a temperature above that of the cold body, then evidently we can insert an auxiliary heat engine between the intermediate body and the cold body, by means of which a part of that rejected heat can be turned into mechanical energy, without abstracting any additional heat from the hot body. And again, if the intermediate body receives heat from the hot body at a temperature less than that of the hot body, it may evidently be supposed to do so through the agency of an auxiliary heat engine, which receives heat from the hot body and rejects it into the intermediate body, the effect of which is to increase both the work done and the heat expended by *equal* quantities, and thus to increase the efficiency of the process.

Thus we see that the conditions of maximum efficiency of all heat engines are the same as those of the simple kind of engine considered in previous articles.

And more than that, the value of the maximum efficiency must be the same, for it will be seen, on referring back to the last article, that the argument holds equally good if the engine working forwards have the same or a different intermediate body from the engine which is working backwards.

Thus the conclusions stated with reference to the simple engine hold good with reference to any possible heat engine, and these general conclusions constitute the "second principle of the mechanical theory of heat," which may be otherwise briefly stated thus :—

The efficiency of every reversible engine is $\frac{T_1 - T_2}{T_1}$ *and is greater than the efficiency of any other heat engine working between the same limits of temperature.*

21. Let us now imagine the temperature T_1 of the hot body, or source of heat, to be divided into n equal parts, and let us imagine a quantity of heat Q to flow from that body to a second body, the temperature of which is $T_1 \left(1 - \frac{1}{n}\right)$, then our results show, that a quantity $\frac{Q}{n}$ of mechanical work is capable of being produced, and that consequently, if such conversion be effected, the quantity of heat $\frac{n-1}{n} \cdot Q$

will pass into the second body. Now imagine a third body, the temperature of which is $T_1\left(1-\frac{2}{n}\right)$ and let this heat pass from the second body to the third body; then the heat capable of being turned into work is

$$\frac{n-1}{n}\cdot Q\cdot\frac{T_1}{n}\cdot\frac{1}{T_1\left(1-\frac{1}{n}\right)}$$

that is $\frac{Q}{n}$ as before. This process may be continued indefinitely, and we thus see that—*If the temperature of a source of heat be divided into any number of equal parts, then the effect of each of these parts in causing work to be performed is the same.*

It is in this form that Rankine enunciates the "second principle," and his view may be illustrated by the analogy which exists between the difference of level, which causes work to be performed by an hydraulic machine, and the difference of temperature which causes work to be performed by a heat engine. Each foot of fall in a water-wheel is equally effective in doing work by means of the water-wheel, and just so each degree of temperature passed through during the passage of heat from a hot body to a cold one is equally effective in causing work to be done by a heat engine working by means of this heat.

The temperatures in question are, as our investigation shows, to be measured on the perfect gas thermometer, which is, therefore, entitled to be considered as a definite measure of temperature. Temperature, being by its nature incapable of direct measurement, we can only measure it by considering some physical effect which difference of temperature produces; thus the ordinary mode of measurement is, by observing the expansion which bodies undergo when their temperature is raised. This, however, is inconvenient for scientific purposes, since no two thermometers give exactly the same results; for instance, the mercurial and air thermometers, if graduated to indicate correctly the temperatures of melting ice and of water boiling under a given pressure, will be found to differ at intermediate temperatures. We must, therefore, consider some other physical effect due to difference of temperature, and the only one known to be independent of the particular body operated on is the power of which we have just been speaking, which difference of temperature possesses of converting heat into work. If equal intervals of temperature be understood to mean equal capability of converting heat into work, we get a scale of temperature which may, with propriety be called *absolute*, and which as our investigation shows, coincides with that of the perfect gas thermometer, that is (sensibly) with the air thermometer; and the term "absolute," already applied to temperature measured in this way, is hereby justified.

(To be continued.)

THE EUROPEAN MEASUREMENT OF A DEGREE.

Translated Extract from "Allgemeine Bauzeitung."

The results obtained by the various measurements of a degree for the determination of the form of the earth, differ very considerably. In the several cases in which the method of least square was employed, values were obtained for that elliptic spheroid to which the figure of the earth approximates very closely. In this way Bessel from the results of 16 measurements found the oblateness,

$$0=\frac{1}{299.1528}\pm 0.000039234$$

the length of semi-major

$$a = 3272077.14 \text{ toises};$$

that of the semi-minor

$$b = 3261139.33 \text{ toises};$$

the length of the degree of the meridian at the mean latitude ϕ,

$$l = 58013.109 - 286{,}337\cos 2\phi + 0.611\cos 4\phi + 0.001\cos 6\phi \text{ toises};$$

the length of a degree of the parallel

$$l_1 = 57156.285\cos\phi - 47{,}825\cos 3\phi + 0.060\cos 5\phi \text{ toises}.$$

Airy has made calculations based on 14 measurements and finds

$$0=\frac{1}{299.33};\ a=3272119.6.$$
$$b = 3261188.4.$$

These results differ little from those obtained by Bessel.

James's calculation of the length of the radius of the meridian circle at the latitude ϕ is interesting. Employing the formula

$$r = A + 2B \cos 2\phi + 2C \cos 4\phi,$$

and finding the values of A, B, and C, from the results of actual measurements, we have

$$A = 3267074.2;\ 2B = 16820.1;\ 2C = 244.3;$$

while to the elliptic form of the meridian correspond the values

$$A = 3266973.5;\ 2B = -16681.8;\ 2C = 35\ 5.$$

The agreement in these results warrants the conclusion that the figure of the earth is that of an ellipsoid of rotation about its minor axis.

After the completion of the measurement of the arc between Formentara and Dunkirk, France undertook and accomplished the measurement of about 13 deg. between Ravenna and Padua. For a mean length at 45 deg. 43 min. 12 sec. longitude, the result was 77862.6 metres; a deviation of 192.95 metres from the extreme value. On this account another survey was undertaken from Brest through Strasburg and Paris to Munich. The results have not yet been published. Another important survey was conducted by the Prussian General Müffling, which extended from the Observatory at Gotha, to Dunkirk. Two sections of this arc gave respectively an ellipticity of

$$\frac{1}{316\ 1} \text{ and } \frac{1}{315\ 2}$$

The most extended measurement was initiated by Struve. This extends from the east of Europe to the west of Ireland. It is nearly (1870) completed. The electric telegraph has been employed in determining the differences of longitude.

It is well known that the ellipticity of the earth has been determined by means of the pendulum; whose period of oscillation varies with the latitude and with the radius at the place of observation. The first experiments were made by Boguer; and the result was $0 = \frac{1}{35.6}$. Mathieu found $0 = \frac{1}{298.2}$ on the French meridian; while Sabine, from 25 observations between −13 deg. and 80 deg. latitude, found $0 = \frac{1}{289.1}$. Freycinct calculated $0 = \frac{1}{286.2}$ for the southern hemisphere.

The last European measurement of a degree will fill a gap in the former surveys; *i. e.*, between the Paris-Berlin-Dorpat meridians and between the longitudes of Palermo and Christiania. It will also contribute to the settlement of the question, whether the discrepancies in results are due to the irregular figure of the earth, or are to be accounted for by the deviation of the plumb-line. This deviation may be caused by the attraction of mountains, as was observed by Boguer in the Cordilleras, by Maskeleyne at Schehallien, by Maclear at the Cape of Good Hope, and by Carlini at Mount Cenis; or it may be due to different densities of the interior portions of the earth, as was assumed on the Italian plain; or to geologic diversities, as was conjectured in the Russian survey.

When the general figure of the earth has been determined, there still remain questions concerning local deviations, such as particular oblateness in different sections, different curvatures of the sea, etc.

THE HENDERSON PROCESS.

From "Engineering;"

About eighteen months ago attention was directed in many quarters to a process of subjecting pig iron to the combined action of fluorides and oxides, and it was asserted that by these means an exceedingly pure product could be obtained for use as wrought iron, or for conversion into cast steel of excellent quality, notwithstanding that the original cast iron, in respect of its phosphorus and other deteriorating ingredients, might have all the evil repute that attaches to Cleveland and other inferior classes of iron. Not much more was heard of the process for

a time, but as it has been tried in this country, and on the Continent, within the past few months, and as we are in possession of some of the results of the experiments, we propose laying a brief statement regarding the process before our readers. From the title of this article, many of our readers will, naturally enough, and quite corectly, conclude that the process in question is the fluorine or fluorspar process, devised and patented by Mr. James Henderson, of New York, a gentleman who has done much for the development and extension of the iron mannfacture in America.

Before coming to this country, Mr. Henderson had made many experimental investigations in American iron works. One plan of carrying out the principle of Mr. Henderson's patent is to use a mixture of finely-ground fluorspar and native oxide of iron in the pig bed, so that the iron from the blast furnace may be cast in plates or slabs about an inch in thickness, the intense heat of the iron during the process being sufficient to decompose the fluoride of calcium and oxide of iron, and thereby liberate fluorine and oxygen to act upon the silicon and phosphorus in their escape upwards into and through the liquid. We have lately seen this operation put in practice at the Summerlee Iron Works, Coatbridge, but we have not yet learned what sort of bar iron the resulting cast iron has yielded, nor if it has even been operated upon. In other experiments of a similar sort, however, Cleveland pig iron so treated has yielded at Walker Iron Works, on the Tyne (Messrs. Losh, Wilson, and Bell's), excellent bar iron, as indicated by the tests for tensile strength, made by Mr. David Kircaldy and by the analyses made by competent analytical chemists. And the same kind of treatment applied to foundry iron, at the Almond Iron Works, near Falkirk, in Scotland, produced according to Mr. Binnie, of the Falkirk Iron Works "very soft castings, and as solid as a bell." Forge iron treated in this way in the pig bed requires no further "physic," to use the language of the workmen in the puddling furnace; and when forge iron is used in the refined condition obtained by the use of fluorspar, the heats from the puddling furnace are got out in an hour on the average, including the charging, melting, puddling, balling-up, and removing from the furnace. The Henderson refined metal is stated to contain, as a rule, no silicon, owing doubtless to the extraordinary degree of affinity which fluorine has for that element—a degree of affinity which is familiar to every student of chemistry; and in respect of silicon and phosphorus it is affirmed to be as pure as wrought iron. If such results can really be always insured in practice, of course a most marked progress has been made towards perfecting the manufacture of iron; but we cannot shut our eyes to the fact that similar results have been claimed to have been effected by other chemical processes previously tried, but which have ultimately proved defective in practice.

Mr. Henderson does not limit himself to the treatment in the pig bed, as already briefly described; he also aims at effecting in the puddling furnace the complete process of purification, including decarbonization. Hitherto, however, he has used the puddling furnace alone, whereas that is the least economical method of operating. The plan which he aims at carrying out is to have a cupola furnace in which the pig iron is melted, and then run into one or more of a set of puddling furnaces surrounding it, and on the bed of each, of which the required quantity of fluorspar "physic" has previously been spread. It should be mentioned that, in addition to fluorspar, the patentee uses in the mixture he employs pure rich iron ores, ilmenite or titaniferous ironestone, clay, and carbonate of manganese in varying quantities.

The most elaborate series of trials made by Mr. Henderson are those which have just been concluded at Blochairn Iron Works, Glasgow. They extended, with one or two interruptions, over several months. Almost all brands of Scotch pig iron were operated upon, as also several brands of Cleveland iron. Many of the specimens obtained are now in the hands of eminent chemical analysts and Mr. Kirkaldy, and therefore we are precluded from saying anything regarding their chemical purity or mechanical properties; but the products have received a high character from many skilled practical men who have examined them. The process has also been approved by Messrs. Hannay and Sons, of Blochairn Iron Works, the most extensive manufacturers of finished iron north of the Tweed, and

we understand that they have resolved to take a license from the patentee for working it. Clarence forge iron and Consett white cinder iron is stated to have yielded at Blochairn bar iron of the first quality; and Dalmellington No. 4 forge pig iron gave a product which, as a single-worked plate, flanged perfectly in the cold, and in which the sulphur was reduced to .04 per cent., and the phosphorus to .07 per cent., and in which the total impurities only amounted to .12 per cent. In all iron which has been subjected to a puddling process, however, so much depends upon the manner in which the puddling is performed, that it is difficult to found an opinion on a few isolated results.

Within the last few weeks, Mr. Henderson has brought his process practically under the notice of the proprietors of the Gilmont-Dupont Crespin Works at Blanc Misseron, in the North of France and of MM. Jowa and Cie., at Liege; and so satisfied were the proprietors of both works with the results, that they resolved to institute trials themselves on a large scale. The patentee operated upon Grosmont mottled pig iron, and is stated to have obtained No. 3, or best iron; on B. S. Newport, and obtained best, or No. 4, according to the French classification; and on Moselle pig iron containing 2 per cent. of phosphorus, and 1 per cent. of sulphur, obtaining from it finished iron classed as No. 3, or best.

More recently Mr. Henderson has had some of the bar iron which was made from mixed numbers of Clarence pig at Blochairn converted into cast steel at Messrs. Stones and Campbell's Steel Works, Govan, near Glasgow. The first sample of this product was pronounced excellent by Mr. Stones. If really good tool steel can by this process be made from Cleveland pig iron, and at a nominal cost, or, at all events, at not more than the ordinary cost, then Mr. Henderson is on the high road to achieve a reputation probably equal to that of Mr. Bessemer; but while we have every disposition to regard the fluorine process favorably, we require to be in possession of far more extended and exact data as to its practical capabilities before we can speak of it in the sanguine tone which is already adopted in some quarters concerning it.

REPORTS OF ENGINEERS' SOCIETIES.

MASSACHUSETTS SOCIETY OF ARTS.—At a recent meeting of the Massachusetts Society of Arts, the president J. D. Runkle, in the chair, Mr. Edmund H. Hewins read a communication, well illustrated by photographs projected upon a screen by the calcium light, on European and American bridges, and compared the cost and methods of building bridges in the two countries.

It is now generally acknowledged that the "truss" is the form which admits of the greatest economy in the use of material; and yet there are some engineers who cling tenaciously to the old plate or box girder. A few years since, an engineer of wide reputation and large experience condemned a truss bridge, giving as a reason that the peculiar construction would cause the iron to crystallize from the trotting of horses over it. The bridge was consequently built as a plate girder, and the cost was more than fifty per cent greater than it would have been for a truss bridge.

The days of tubulars, girders, etc., have substantially passed away; there will be no more Britannia or Victoria bridges; they stand as vast monuments of indomitable will and energy. All honor is due to Stephenson for building the bridge over the Menai Straits; considering the then limited knowledge of the use of iron in bridge building, it is a monument worthy to make his name famous for ages to come.

Brunel has done even more; the Saltash is a conception more gigantic, and as much a flight of genius—a work which will remain when the other is destroyed by time.

Truss and lattice bridges now predominate, the latter being but a form of the first.

The bridges of Europe are secured together by almost innumerable rivets; the various parts being usually composed of plate and angle iron riveted into box and other forms best calculated to resist the storms to which they may be subjected. The building of parts in this manner requires much care and is very expensive. The rivet holes deduct a considerable amount from the strength without reducing the weight.

A strut or tie composed of several pieces riveted together has not an effective strength proportioned to its section, for it is impossible to bring the different pieces to an equal strain at the same time. The engineer has here to make an allowance which is a very variable quantity. The ties and struts are rigidly connected with the chords.

Whenever a load comes upon a bridge there must be some deflection; this causes a distortion of the form of each panel, and as the ties and struts are rigidly connected to the upper and lower members, a powerful leverage to bend them is the result, and there is at the same time an increased strain upon the rivets.

In the crossing of a railway train or other partial load, the counters, neccessarily, not being in readiness to receive their proper strains at the proper moment, allow an undulation which materially increases the bending strains upon the ties and struts. This occurs every time a train or locomotive crosses the bridge.

The trusses used in American and European bridges are very similar, the essential difference being in details of construction, which in the European bridge are very expensive, as so much hand

labor and fitting is required. A large amount of material is used which is mere dead weight, being of no use in sustaining the load or itself. The action of such a bridge is necessarily unsatisfactory from the fact that certain portions receive strains in practice which are not legitimate, and consequently must tend to shorten its life.

The following data were collected in Europe by Mr. David Busk. The viaduct of Fribourg, on the Orleans railroad in France, is composed of eight spans of 160 ft. each, and has a height of 250 ft. above mean low water of the Sarine. The piers have a masonry foundation 89 ft. high, with a metallic superstructure of 142 ft. The total length of the viaduct is 1299.88 ft. and cost, above the masonry, $366,000 in gold, or $282 per lineal ft. The figures for three other viaducts on the Orleans Railroad are as follows:—

The viaduct of the Bouble.

6 spans of 164 ft. each, total length.....	984 ft.
Height above masonry, average.....	138.76 ft.
Cost per lineal ft.....	167 dols.

The viaduct of Bellou.

3 spans, average length 140 ft., total	420 ft.
Height above masonry.....	137.76 ft.
Cost per lineal ft.....	123 dols.

The viaduct of Neuville.

2 spans of 161.13 ft. each, total length...	322.26 ft.
Height above masonry.....	136.18 ft.
Cost per lineal ft.....	112 dols.
1 span.....	77.08 ft.
Cost per lineal ft.....	108 dols.

The American Truss Bridge instead of being bound together in one solid mass, is composed of various members, each independent of its neighbor, so far as it own work is concerned, each having a specific and defined duty to perform, and proportioned accordingly. By no change of temperature, or variety of loan in amount or position, can any but legitimate strains be imposed upon any part. The joints are made with pin connections, so that a deflection can bring no twisting or bending strain upon any of the parts—and though the form of each panel be very much distorted by an approximation to the breaking load, no excess over the proper strain can be brought to bear on the bridge. Each part is known to receive its proper strain at the proper time, as they are made adjustable in all directions, and by this means the vibration and undulation are reduced to a minimum. American bridges have astonished the world that such light structures should have so little deflection and undulation.

American bridges are cheap to build. Most of the work is done by machinery instead of hand labor, and but little skilled labor is required.

Work done by machinery does not cost one half as much per pound as work done by hand. Considerable expense is also saved in handling and erection.

It is sometimes necessary to erect bridges over streams which are liable to rise suddenly and sweep away the temporary works. In such a case, the loss would be incalculable in time and money, if the bridge should be carried away.

Our bridges—built as they are in parts which are seldom too heavy for two or three men to handle—can be erected in a very short time.

A 200 ft. span could be swung clear of the staging in three or four days, while the plate girder lattice, or European truss would require as many weeks. The average cost of railroad bridges in America is about one half as much in currency as European bridges cost in gold.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.—A Paper was read by Captain Seddon (R.E.), On the Necessity and Method of Testing Building Materials. He contended that the most successful architect or engineer was he who obtained the most successful results with the least expenditure of money and labor. The great problem of the day was, how most successfully to economize money and labor. The extensive use of iron for constructive purposes might be said to have given birth to civil engineering, in contrast to architecture, and this had been attended with somewhat disadvantageous results. Perhaps architects had confined themselves too exclusively to the study of the beautiful, and engineers, affecting a superiority for such ideas, had too much neglected art. There was also a ministerial authority for banishing art from ordinary structures, and confining it only to churches. Whilst there was necessarily a radical difference between engineering and architecture, he thought the members of both professions would do better by working more together. In striving to obtain the best results from the least outlay of money and labor, architects and engineers both stood on the same footing; but it was a question whether they were sufficiently acquainted with the properties of the different materials which they employed. It might be said that there were handbooks in existence giving all needful information about materials and their properties; but he thought it must be admitted that their knowledge was not so satisfactory as could be wished. Experiments had mostly been tried on specimens which were too small, or were defective; and the results, therefore, were not reliable. Molesworth, the author of a handbook on Engineering Formulæ, differed considerably from Hirst, who had compiled an architectural handbook respecting the tensile strain of materials; and there was, in fact, a mass of conflicting evidence on such subjects. Even the seasoning of the specimens tested would account very much for the different results arrived at, and a natural adhesion of the fibres made a vast difference. Notwithstanding the experiments and researches of Mr. Kirkaldy, it was clear that there was yet a great deal to be learnt about iron, and misconceptions prevented what could only be swept away by a series of practical experiments. Iron was now forcing its way everywhere; and it was requisite that they should not merely order a girder, but also be thoroughly acquainted with the material, as there was nothing so dangerous to trust to as iron, and no material which admitted of so much deception on the part of the dishonest manufacturer. The different strength and properties of various descriptions of iron were remarkable. In order to insure having a proper kind of iron, they should get it tested beforehand; the elasticity and ductility of the metal must be ascertained, in addition to its compressive and tensile strength. Many obsolete notions about iron were still retained, and cold grey iron was supposed to be required for particular purposes; but they did not get it from the contractors. The effect of different degrees of temperature upon the ductility of iron was worthy of inquiry. When subjected to great heat, iron would lose its ductili-

ty; and it was injurious to expose a hard metal to extreme cold. In the forging of iron rivets great attention was necessary, and they were liable to be injured by remaining in the fire too long. With regard to wood, he called attention to various experiments which had been made on large sections, and the results, he thought, would be different from those arrived at in experimenting on 2 or 3-in. specimens. In testing building stones the recorded results differed very widely, so that if they trusted to a handbook, the strength of their materials might be supposed to depend upon what particular work they consulted. A preference was frequently exhibited for Coreham Down stone over Boxford ground stone, but it was doubtful whether any superiority existed; only one description of stone was more expensive because it was more difficult to procure. The artificial dressing of stone should not be resorted to. With regard to the strength of sandstones, the information upon the subject was very meagre and unreliable; and it was clear that more knowledge was required respecting the special qualities of different kinds of stone and their applicability to different uses. In experimenting upon stone, they ought to know all about it—the quarry where it came from, and perhaps even the particular bed in the quarry. He also advocated a careful series of experiments upon the artificial stone called concrete, which he believed would be very useful; and contended that architects should do all in their power to carry out a careful course of experiments for the purpose of testing the various materials they employed, as by these means all doubts and doubtful theories might be cleared away, and conclusive results obtained. He would recommend a visit to Mr. Kirkaldy's testing works at Southwark; his machinery was so perfect, that his experiments might be depended upon. It was by men of Mr. Kirkaldy's stamp that the world had been benefited; but the world often forgot its benefactors. Then came the question, who should pay for the experiments? He replied—the manufacturers, and those who wished to supply materials; they ought to send them to Mr. Kirkaldy's works to be tested beforehand. The cost of the experiments would then fall upon the right shoulders, and he believed this plan had been already carried out to some extent.

ASSOCIATION OF ENGINEERS IN GLASGOW.—At the monthly meeting of this Association—the President, Mr. John Sutherland, in the chair—Mr. Alexander Reid read a paper on "Time Allowances for Yachts in Racing," in which he alluded at considerable length to the various methods employed in computing the scales of allowances in this country and in different parts of America. The principles on which these various scales are constructed were carefully examined, and the insufficiency of most of them to meet all cases clearly shown. It was maintained that, as the most correct means, the allowances should be made in proportion to the displacement of the vessels. A discussion followed the reading of the paper, in which there was much interest taken.

PARIS SOCIETY OF CIVIL ENGINEERS.—At a recent meeting a report was received from M. P. Thomas, which he had been instructed to make on the new oxyhydric light of M. Tessie du Motay. The report is limited to a technical examination, apart from the economical question, and the following are the conclusions arrived at:—1. Theoretically, the combustion of oxygen does not increase the illuminating power of a given volume of gas. 2. Practically, however, it enables a burner to consume four times the quantity of gas that can be burnt in air, without detriment to the utilization of the light developed. In particular, it realizes the entire luminous capacity of gases, however rich, in almost any quantity.

Consequently, it would be disadvantageous to supply it for ordinary street-lighting, on account of the limited consumption of the burners in use.

Its use presents no other great advantage, except as to the beauty of the light, for small burners supplied with very rich gas.

But it is very advantageous—and the more so in direct proportion to the richness of the gases employed—for great centres of light (sun-burners, etc.), where a large volume of gas my be consumed without loss. With reservations in relation to the proportion of the total quantities of gases consumed (oxygen and hydrogen) and the resulting illuminating power developed.

The foregoing is not the only report to be made upon the subject, as M. Leblanc, it is understood, is commissioned to report thereon for the city authorities.

THE ROYAL SOCIETY.—The "Decomposition of Water by Zinc in conjunction with a more Negative Metal" was the title of a paper by Messrs. J. H. Gladstone, Ph. D., and Alfred Tribe, F. C. S. Pure zinc is incapable of decomposing pure water, even at 100 deg. Cent., but at a considerably higher temperature it is known to combine with its oxygen. Davy exposed pure water for two days to the action of a pile of silver and zinc plates, separated only by pasteboard, without obtaining any hydrogen; Buff, however, had shown that a very minute trace of gas can be formed at the ordinary temperature by a pair of zinc and platinum plates. By bringing the metals close together, and thus increasing the electrical tension of the liquid, the authors could effect the same combination of zinc with oxygen at the ordinary temperature which takes place, without the second metal at a very high temperature. On thin sheets of zinc and copper being hammered together, and placed in a bottle filled with distilled water, small bubbles of gas were formed; the same result obtained when the experiment was tried in a more perfect form. Under the microscope the bubbles of gas are seen to form, not on the zinc, but among the copper crystals, and sometimes to make their appearance on the glass at some distance off. Lest it might be contended that the free oxygen usually present in distilled water had been the means of starting this action, the experiment was repeated with water as free from oxygen as could be obtained by boiling. Iron and lead under similar circumstances, also decomposed pure water, and the action of magnesium was greatly increased by conjunction with copper. The effect of the more negative metal was the same as would have been produced by an increase of heat. From a practical point of view this experiment may serve as a ready means of preparing pure hydrogen; from a theoretical point of view its interest seems to lie in the fact that the dissociation of a binary compound by means of two metals may take place

at infinitesimally short distances, when it would not take place were the layer of liquid enough to offer resistance to the current, and also in the correlation between this force and heat.

IRON AND STEEL NOTES.

BRITISH IRON TRADE.—It is a matter of great interest to the British iron trade to inquire what are the future prospects of the American demand for British iron, and especially British railway iron. The exports of our railway iron to the United States in the first three months of this year compared as follows with the exports of the corresponding periods of 1871 and 1870:

Month.	1870.	1871.	1872.
	Tons.	Tons.	Tons.
January....	24,610	28,264	28,648
February...	32,957	32,784	53,131
March	23,222	41,917	41,175
Total....	80,789	102,965	129,605

It will be seen that while the exports presented a slight advance in January, as compared with January, 1871, and a considerable advance in February, as compared with February, 1871, they reflected in March a slight check in the American demand for our railway *materiel*. The question of questions, which now awaits solution, is whether this check is attributable to the higher and higher prices which have gradually become current for British iron, and whether, under the circumstances now existing, the Transatlantic demand is likely to be maintained at its present or former level. The gravity of this question will at once be seen by the annexed analysis, indicating the proportion borne by the exports of our railway iron to the United States to the corresponding exports in all directions:

Quarter ending March 31.	1870.	1871.	1872.
	Tons.	Tons.	Tons.
Whole export...	209,151	174,479	201,321
To United States	80,789	102,965	129,605
Balance.....	128,362	71,514	71,716

These figures indicate two results—first, the extreme relative importance of the American demand; and secondly, a great falling off in the general external demand for our railway iron. There can, we fear, be only one conclusion formed from an examination of the statistics, viz., that high prices are producing their usual inevitable result of restricting consumption. It is time, in short, that the British iron trade—and especially the operative members of it—should understand that quotations for iron cannot go on advancing forever, without frightening away intending purchasers. * * * * * * *

The dearness of English iron would appear to have given a great impetus to the production of iron in the United States. In 1871, the make of pig iron in the great Republic was estimated at 1,912,608 tons; this total was scarcely so large as the corresponding figures for 1869; but when we go back to 1861, we see that very great progress has been made in the manufacture of American pig iron, the output for 1861 having been only 731,544 tons, or considerably less than one-half the total attained last year. In 1871, the United States imported 572,386 tons of rails, of which 511,059 tons were supplied by Great Britain, the balance of 61,327 tons being obtained principally from Belgium. In the same year, the Americans made themselves 775,733 tons of rails, four states supplying more than 50,000 tons each, viz., Pensylvania, 335,604 tons; Illinois, 91,178 tons; New York, 87,022 tons; and Ohio, 75,782 tons. The Americans possess almost inexhaustible supplies of coal and iron minerals, and their metallurgical industry, already important, might acquire, in a few years, a very great development, if prices continued high in Europe. The Americans have not imported large quantities of English rails because they cannot make rails for themselves, but simply because it has hitherto been cheaper to import rails from Great Britain than to make them —at any rate, in every case—at American rail mills. Destroy the cheapness of English railway material, and you cripple and restrict the market for it in the United States; and not only the marked for it in the United States, but the market for it throughout the world. This is a consideration calling for the most earnest attention on the part of all connected with the British iron trade.—*Colliery Guardian.*

GERMAN AND FRENCH STEEL.—The "Bulletin of the French Committee of Forges" gives an interesting comparison on the production of steel in Germany and France. The former country produced, in 1860, 25,312 tons, and in 1869 not less than 163,319 tons of cast steel, being 6.37 times more than 9 years before. From 1864 to 1869 France, however, saw her production of steel, principally Bessemer steel, multiplied 29 times, which was in 1869 actually 52,000 tons. The first half year of 1870 shows a production of 44,419 tons, and when the steel industry of France shall have overcome once more the difficulties which it has suffered under the war, her annual steel product may be estimated at 90,000 tons. Germany increases her number of steel works almost daily, and will most likely remain ahead of France for some good time to come.

The Terrenoire Works are stated to have forwarded steel rails to the United States last year to the value of $150,000. This is believed to be the first occasion upon which French works have established business relations with the American railway interests.

THE territory ceded by France to Germany contains 25 blast-furnaces, producing annually 555,000 tons; and 9000 hectares of coal and ironstone beds, of a yearly yield of 180,000 tons. An iron-masters' association in the Longwy district contemplates the erection, in France, of new works.

RAILWAY NOTES.

WHARTON RAILWAY SWITCH.—This new thing under the sun presents many desiderata, indispensable to such appliances for assuring, at once, safety, economy, and ease of operation.

Prominent among its excellencies is the fact of its granting switch facilities *without breaking the main line* and endangering through travel. For those unacquainted with the peculiar difficulties besetting the accomplishment of such an object, the above statement may not carry weight; but to experienced railway men it is interesting and valuable.

In construction, this switch is simple and peculiarly enduring,—all the wearing parts being of solid steel and only borne upon by cars entering or leaving sidings, the main track (by a peculiar and new arrangement) being used exclusively by the trains running over it without in the least affecting the "switch track." In practical operation it affords what is still more valuable, viz.: perfect security to trains in case it is left wrong, either accidentally or by malicious design,—for your switch-tenders will sometimes take a fancied revenge upon their employers by such dastardly means, and in all such cases no injury is done to the switch itself. Targets and signals, moreover, for indicating the position of the switch on double-track roads, are dispensed with; while on single-track roads it wil not remain set for a siding, should the tender forget his duty.

Without diagrams it is almost or quite impossible to convey any full idea of the movements of this invaluable invention; and we are compelled to forego a detailed description of it for that very reason. In general, however, we call attention to one rather important feature: None of the accidents heretofore so frequent from the bending or breaking of connection-rods, or of any of the moving parts, can possibly ensue in the use of the Wharton switch, since the main track is absolutely immovable (being spiked to the cross-ties), and for other reasons unexplainable without illustrations.

This invention is presented to the public with the commendations of several practical railway managers—prominent among them being Hon. Thos. A. Scott, of the Penn. R.,—who attest its trustworthiness. Mr. Scott certifies: After careful "experiment upon our road at several points where it could be *most thoroughly tested*, we think it adapted to all our wants. We have concluded to adopt it on our own and our leased roads, and will give it place as rapidly as we can. I believe it will prove of great practical value to all railways."

Such an indorsement has valuable significance both to the owners of the invention and to a grand army of railway builders or projectors.

AN IMPORTANT PENNSYLVANIA NARROW GAUGE.—In pursuance with the charter, the Montrose Railway Company was organized April 27, 1871. At the first meeting of the Directors, May 27, 1871, it was directed that the engineers survey and locate from Tunkhannock to Montrose. The report of its President, James L. Blakslee, Jan. 8, ult., shows a favorable prospect for the completion of the road by August next. The Lehigh Valley Railroad Company has agreed to furnish the rails, ties, spikes, and splices as soon as the grading has been completed and paid for; agreeing, also, to receive their pay in stock at par.

The Engineer reports that the survey commenced May 15, 1871. The work is now under contract and progressing favorably. Length of road, 27 $\frac{12}{100}$ miles. Commencing at Tunkhannock, the first summit is found at $4\frac{26}{100}$ miles; average ascending grade per mile (excluding levels), 93 ft.; the next summit is $7\frac{25}{100}$ from Tunkhannock, ascending grade 26 ft.; the grade then descends to Meshoppen Creek, $10\frac{15}{100}$ miles, with average descent of 40 ft. per mile. The next summit is $16\frac{33}{100}$ miles; average ascending grade from Meshoppen Creek, 85 ft. From this summit this grade is level for 1 mile. From this to the next, $19\frac{45}{100}$ miles, the average ascending grade is 71 ft. per mile. From there to the next summit ($23\frac{54}{100}$ miles from Tunkhannock), the grade is undulating, nowhere exceeding 85 ft. ascent and 63 ft. descent. From the latter to Montrose it is also undulating, nowhere exceeding 80 ft. ascent and 60 ft. descent. There are two 18 deg. curves—all the others being only of 16 deg. There will be two bridges, each of 100 ft.—one spanning the canal at Tunkhannock and the other, Meshoppen Creek. Also 600 ft. of trestling of average height of 26 ft. The road is under contract to be built ready for track laying for $101,000, which sum can be taken for approximate cost of grading, masonry, bridges, etc. The estimated cost per mile is $5,733. Total cost, including rolling stock, equipments, station houses, etc., $341,478. The gauge adopted is 3 ft. Says the President, in summing up:

The probabilities of this road paying fair dividends can be inferred from the following facts:

It passes through the centre of the populous county of Susquehanna, which is a rich agricultural region, with but little waste land. The farms are all well improved and the land is specially adapted to dairying and grazing. The road makes available the valuable water power at the outlet of Marcy's pond, and on the Meshoppen Creek. It runs into the borough of Montrose, the county seat of Susquehanna county, which is a flourishing business and manufacturing centre, and has no other railroad communication.

Estimate of the annual revenue and expenses:

From freight on 12,000 tons of coal, at $1.25		$15,000
On 12,000 tons lumber and bark, at $1.00		12,000
On 12,000 tons miscellaneous, at $1.60		19,200
From passengers		12,000
From mail and express		4,000
Total		$62,200
For operating and maintaining road, etc.	$28,000	
For dividends, 10 per cent. on the capital of 342,000	34,200	
		$62,200

THE RAILWAY INTEREST.—It has lately been shown that 14,247 miles of railway are now being worked in the United Kingdom, on which have been expended a sum of more than £500,000,000, which is 5 times the amount of the annual value of all the real property of Great Britain, and $\frac{3}{4}$ of the national debt. The gross net annual revenue of the railways in this country, after deducting all working expenses, exceeds £22,000,000, more than the total revenue from all sources of Belgium, Holland, Portugal, Denmark, Sweden, and Norway. The companies have in their direct employment more than 100,000 officers and servants. The value

of the rolling stock exceeds £30,000,000. The consumption of coal and coke by railway engines amounts to between 2,000,000 and 3,000,000 tons a year; so that in every minute of time throughout the year, above 4 tons of coal are consumed, and 20 tons of water are flashed into steam. The consumption of fuel is about equal to the amount of coal exported from Great Britain to foreign countries. There are more than 3,000,000 tons of iron laid down in rails alone, and the chairs would weigh nearly 1,000,000 tons; so that there are not far short of 4,000,000 tons of iron on the permanent ways of the United Kingdom, and of these about 30,000 tons of rails have to be every year replaced. No one will deny that our railways make a figure in the world.

ENGINEERING STRUCTURES.

THE TUNNEL UNDER THE MERSEY.—The tunnel which is to connect Birkenhead and Liverpool has been commenced. The trade in the Birkenhead Docks has been very much retarded for the last few years, and prevented from ever attaining its proper dimensions by the want of sufficient means for the transit of goods from Liverpool. The tunnel according to the "Birkenhead and Cheshire Advertiser," will be about 3 miles in length, about one-third of which will be under the bed of the river Mersey, and will connect nearly all the railways in England with the Birkenhead Docks. The preliminary operations for the formation of the tunnel have been completed. A hoarding has been erected on the South Reserve land, between Shoreroad and the river, close to Woodside Ferry, and on Monday a number of workmen commenced preliminary operations for sinking a shaft in order to attain a depth of 70 ft. below the bed of the river, at which point the cutting of the tunnel railway will be undertaken. The tunnelling will be performed with two machines, each of which will make a cutting 15 ft. in diameter with a pressure of 30 horse-power engines. Two other shafts will be sunk on the Birkenhead side, one on the upper side of Shoreroad, and the other between the gasworks and Green-lane, Tranmere, where will be situated what may be called the Cheshire terminus, the line there joining the Birkenhead and Cheshire railway, thus giving direct access from London into Liverpool, under the Mersey. As most of the materials dislodged in the cutting will be brought to bank at Birkenhead, it will be some time before the work commences on the Liverpool side, the only materials to be brought up there being those displaced in the downward shaft, which will have to be driven in order to reach the eastern end of the tunnel. This will be next the Harbor-master's office. It is anticipated that, unless serious geological "faults" are met with, the cutting of the tunnel, which is to accomodate a double line of rails, will be completed in two years.

RAILWAY BRIDGES IN CANADA.—We have the following from the Toronto "Globe:"

"Survey and soundings are completed for the proposed railway bridge over the Ottawa River, above the Chaudiere. A very feasible route gives a bridge 3,400 ft. long, 2,000 ft. of which will be on land at low water, not over 5 ft., and the depth in the channel is less than 20 ft.

"The engineers employed in taking soundings for the proposed bridge across the St. Lawrence, between Prescott and Ogdensburg, have completed their labors. The bridge will be 3,000 ft. long, and the piers will have to be sunk in 80 ft. of water."

ROSENDALE VIADUCT.—A magnificent iron bridge at Rosendale, N. Y., begun in September last, is completed. It carries the Wallkill Val. R. across the valley of Rondout Creek and over the Del. & Hudson Canal, running through it. The country being mountainous, the bridge is necessarily put at a very great height above the level of the valley; giving to the structure a picturesque appearance, while its substantial workmanship allays the apprehensions of the most timid traveller.

The superstructure is of the undergrade or "deck" kind; comprising seven wrought iron spans of the Post patent, with two short wooden spans at its south approach. Of the iron spans, respectively, four are 150 ft.; two, 100 ft.; and one, 76 ft. long; the two of wood being each 50 ft.—a total of 976 ft. The trusses are 22 ft. high and 14 ft. apart. A moving load of 3,000 lbs. per lineal foot of bridge, together with the weight of the structure itself, does not tax the bridge to more than one-sixth its capacity. The spans rest on piers, each made up of 6 rectangular wrought-iron pillars trussed with diagonal bracings, arranged so as to obtain the greatest possible rigidity; the iron piers resting upon solid masonry. The height of the bridge between grade line and the water is (at the highest point) 142 ft. The piers are, respectively, 14, 80, 100, 145, 80, 65, and 35 ft. from the ground to underside of the truss. The iron part weighs about 585 tons,—385 distributed among the different spans and the rest among the piers. The cost is: Ironwork about $175,000, and masonry about $50,000.

BOOK NOTICES.

SCIENCE PRIMERS FOR ELEMENTARY SCHOOLS. Under the joint editorship of Professors Huxley. Roscoe, and Stewart. (In 18mo, cloth limp, 50c. each.) Macmillan & Co., 1872. For sale by Van Nostrand.

Of this interesting series of little books, three have appeared, and the announcement of others is shortly promised. We have an introductory discussion by Professor Huxley, and the set of manuals commences with Chemistry by Professor Roscoe, and Physics, by Dr. Balfour Stewart. We are informed that in publishing the Science Primers on Chemistry and Physics, the object of the authors has been to state the fundamental principles of their respective sciences in a manner suited to pupils of an early age. They feel that the thing to be aimed at is not so much to give information, as to endeavor to discipline the mind in a way which has not hitherto been customary by bringing it into immediate contact with Nature herself. For this purpose a series of simple experiments has been devised leading up to the chief truths of each science. These experiments must be performed by the teacher in regular order before the class. The power of observation in the pupils will thus be awakened and strengthened; and the amount

and accuracy of the knowledge gained must be tested and increased by a thorough system of questioning.

This is a novel and ambitious programme: but when Professors Huxley, Roscoe, and Stewart lay their heads together for the production of educational hand-books, something unusual may be expected. Hence, in the little volume of Chemistry, of little beyond a hundred pages, the reader's mind is led step by step from the consideration of one of the simplest processes—the burning of a candle—up to that of chemical proportions, weights, combinations, and equations. For the results aimed at, this method is perfect, and takes the learner through familiar departments, designated fire, air, water earth, non-metallic elements and metals.

Similarly, in Professor Stewart's little volume, the same gradation in the nature of the experiments is kept in view successively through the discussion of natural forces, solids, liquids, gases, motion, vibration, heat, and electricity.

We are certain that in the manner followed, the alphabet of science may be taught to school-boys, and the means of intelligent observation afforded in a way that has never been hitherto exhibited. This is infinitely superior to the meagre and ill-digested smattering of all the sciences conveyed in too many schools and popular lectures.

ATCHLEY'S ESTIMATE AND PRICE BOOK FOR 1873. By W. Davis Haskoll, C. E. etc. Lockwood & Co. For sale by Van Nostrand.

This valuable work maintains its character. Of the amount and diversity of its contents a fair account is embodied in the title-page, running thus:—Atchley's Civil Engineer's and Contractor's Estimate and Price Book for Home and Foreign Service; in reference to Roads, Railways, Tramways, Docks, Harbors, Forts, Fortifications, Bridges, Aqueducts, Tunnels, Sewers, Water-works, Gas-works, Stations, Barracks, Warehouses, etc., etc., etc. With specifications for Permanent Way, for Telegraph Materials, and for Works, Plant, Maintenance and Working of a Railway; and an Alphabetical Priced List of Machinery, Plant, Tools, and Fittings required by the Contractor in the execution of Public Works. The work is well printed on above 200 pages (demy 8vo). There are 30 woodcuts and 3 full-page plates. From obvious causes, books of this class are almost invariably high-priced; this, on the contrary, is uncommonly cheap, and therefore may fairly demand that extensive circulation among intelligent workmen which its merits so highly deserve.

ADVANCED TEXT-BOOK OF GEOLOGY: Descriptive and Industrial. By David Page, LL. D., F.G.S. etc. Fifth edition, revised and enlarged. Wm. Blackwood and Sons, 1872. For sale by Van Nostrand.

The first edition of this admirable work appeared sixteen years ago. It has raised its author from the position of an altogether extra-academical man to that of Doctor of Laws, and to the yet more honorable and important position of Professor of Geology in the College of Physical of Science, Newcastle University of Durham. It is beyond all comparison the best text-book for learners in geology which was ever written in any language. In the short preface to the present edition, Dr. Page says:—"This edition has been enlarged, 1st, to embrace whatever is new and important in the science; 2d, to afford space for additional illustrations; and 3d, to combine, as far as possible, the principles with the deductions of geology. We reason our way to the past through our knowledge of the present, and our descriptions of former epochs become more intelligible and impressive when viewed through the medium of existing phenomena. For this purpose there have been inserted such notices of operations now in progress as seem to bear on the subjects under review—and this in subordinate type, and in such a form as not to interfere with the continuity of the original textual arrangement. These small-type paragraphs should be read with care by the student, for in them he will frequently find the key to the geological problem he is endeavoring to unravel. On the whole it has been the aim of the author to improve rather than enlarge—to keep the volume abreast with the latest discoveries and advancing views of our leading geologists, and yet to prevent it from exceeding the limits of a compendious text-book." The illustrations, the text, and the valuable glossary and index, all bear traces of extension and improvement.

THE CHEMICAL PHENOMENA OF IRON SMELTING. By I. Lowthian Bell. London: E. & F. N. Spon. One volume, octavo, 435 pages, cloth, $6.00. Sent post paid by mail on receipt of price. For sale by D. Van Nostrand.

The character of this excellent work may be judged from the essays of Mr. Bell republished in this magazine, fron the "Journal of the Iron and Steel Institute."

The thoroughly scientific character of the treatise, entitles it to a high position in technical literature, while the great importance of the subject will demand that all who have even the most general interest in the progress of practical science should acquaint themselves with the investigations of Mr. Bell.

In evidence of the thoroughly practical character of the work, we quote the following from the "London Mining Journal:"

"The reactions which take place in every foot of the blast-furnace have been investigated, and the nature of every step in the process, from the introduction of the raw material into the furnace to the production of the pig iron, has been carefully ascertained, and recorded so fully that any one in the trade can readily avail themselves of the knowledge acquired; and we have no hesitation in saying that the judicious application of such knowledge will do much to facilitate the introduction of arrangements which will still further economize fuel, and at the same time permit of the quality of the resulting metal being maintained, if not improved. The volume is one which no practical pig iron manufacturer can afford to be without if he be desirous of entering upon that competition which nowadays is essential to progress, and in issuing such a work Mr. Bell has entitled himself to the best thanks of every member of the trade."

DILAPIDATIONS: A TEXT-BOOK FOR ARCHITECTS AND SURVEYORS.—Mr. Banister Fletcher has revised and reprinted, in a neat volume, his series of articles on dilapidations which appeared in the "Building News" the latter part of last year, and has added thereto a list of the cases cited, an elaborate analysis of contents of each

chapter, and an exhaustive index. The work shows who are liable for dilapidations, what are dilapidations and waste, and instructs surveyors how to take and value them; it is illustrated by examples drawn from the author's experience, and gives the latest legal decisions. It is, in fact a text-book and a standard work of reference for the architect and surveyor on matters appertaining to dilapidations. For sale by Van Nostrand.

ANNUAL RECORD OF SCIENCE AND INDUSTRY FOR 1871: Edited by Spencer F. Baird. New York: Harper & Brothers. For sale by Van Nostrand.

This is designed to fill the place of the "Annual of Scientific Discovery," the publication of which is discontinued.

To the scientific reader or writer, such a yearly record is indispensable.

The matter and its arrangement is substantially the same in character as that of the Annual, with whose features we have been so long familiar.

The typography of the present volume is an improvement upon that of its predecessor.

It is to be hoped that the success of the Record will be such as to encourage the publishers to continue the series.

A TREATISE ON RAILWAY CURVES AND LOCATION. By E. W. Beans, C. E.: Philadelphia: Henry Carey Baird. For sale by Van Nostrand.

This little book contains a series of propositions covering such properties of the circle as are generally employed by railway engineers in the location of curves. It contains but little that is new, and nothing that we could consider an improvement upon the matter already in print in American Field books. The methods given are concisely stated, but are lacking somewhat in logical arrangement. The illustrations are abundant and good.

SPECTRUM ANALYSIS EXPLAINED. Profs. Schellen, Roscoe and Huggins. Boston: Lee and Shepard. For sale by Van Nostrand.

This is No. 3 of the "Half-hour Recreations in Popular Science." We know of no form in which so much sound information is afforded for the price, as in this new series of pamphlets. The present number will probably prove the most attractive thus far to the general reader, containing as it does a complete exposition of this most fascinating department of research, with elegant illustrations.

MISCELLANEOUS.

ALLOYS.—M. Gurttier, in his work on metallic alloys, gives the following directions, which are very valuable, as they are the results arrived at after large experience.

1. To heat the crucible to a red or sometimes a white heat, and then to melt the *least* fusible of the metals composing the alloy. After fusion to heat this metal to such a heat, that it will bear the addition of the next least fusible metal without too great a reduction of temperature.

2. To introduce the metals into the pot strictly in the order of their resistance to fusion, each metal being properly melted before the next is added. The danger in first melting one of the most fusible metals lies in the fact that it would most probably volatilize and become oxidized; this would be a source of great waste.

3. To heat each charge of metal thoroughly before adding it to the pot, thus avoiding as far as possible the reduction of the temperature of the metal in the crucible.

4. When the proportion of zinc is large and some of the component metals have a high point of fusion, the alloys should be covered with a layer of charcoal dust. If the alloys are rich in tin, the surface of the melted metal should be covered with sand.

5. To stir the metal before casting, and if possible when casting, with a white-wood stick; this is much preferable for the purpose to iron.

6. If possible, to add a small proportion of old alloy to the new one. If the alloy is required to make sharp castings, and strength is not a very great object, this proportion of old alloy to the new should be increased. In all cases a new, or thoroughly well cleaned crucible should be used.

STAINING IVORY.—Having seen queries in "Ours" relating to this subject, and having some experience in it, I append a few directions which may be useful to some of "our" readers.

Black.—Lay the article for several hours in a strong solution of nitrate of silver, and expose to the light, or boil the article for some time in a strained decoction of logwood, and then steep it in a solution of acetate of iron. An easier method: immerse frequently in ink until of sufficient depth of color.

Blue.—Immerse for some time in a dilute solution of sulphate of indigo, partly saturated with potash, and it will be fully stained.

Green.—Boil in a solution of verdigris in vinegar until the desired color is obtained.

Red.—Dip the articles first in the tin mordant used in dyeing, and then plunge into a hot decoction of Brazil wood—half a pound to a gallon of water—or cochineal, or steep in good red ink until sufficiently stained.

Scarlet.—Use lac-dye instead of the preceding.

Violet.—Dip in the tin mordant, and then immerse in a decoction of logwood.

Yellow.—Impregnate with nitro-hydrochlorate of tin, and then digest with heat in a strained decoction of fustic, or steep for 24 hours in a very strong solution of the neutral chromate of potash, and then plunge for some time in a boiling solution of acetate of lead.

Horn and bone must be treated in the same manner as ivory for the various colors given above.

HARDENING STEEL CUTTING TOOLS.—The best way is to heat the articles in a coke fire to a blood red heat, and then plunge them into a solution of salt and water, containing one pound of salt to a gallon of water; then polish the articles, heat them over gas or otherwise, till the polished parts assume a pale straw or gold color, and then cool them in the salt and water, if this is well managed, it will make tools to cut anything. The lead process is generally used for hardening files. Best tool steel would not harden by the lead process and stand tempering. Coke fire is generally used for tools for cutting purposes, and I think this process will best answer the purpose.—*Correspondent Mechanics' Magazine.*